Innovation

Invention, Knowledge Transfer, and Innovation

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This publication is part of the *Science and Engineering Indicators* suite of reports. *Indicators* is a congressionally mandated report on the state of the U.S. science and engineering enterprise. It is policy relevant and policy neutral. *Indicators* is prepared under the guidance of the National Science Board by the National Center for Science and Engineering Statistics, a federal statistical agency within the National Science Foundation. With the 2020 edition, *Indicators* is changing from a single report to a set of disaggregated and streamlined reports published on a rolling basis. Detailed data tables will continue to be available online.

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Executive Summary

Key takeaways:

- U.S. patenting and trademark activities are concentrated in certain areas of the country, with the highest rates on the east and west coasts, around the Great Lakes, and in parts of the Southwest.
- U.S. patents are increasingly global. Inventors residing in the United States are named on fewer than half of U.S. Patent and Trademark Office (USPTO) patents.
- Inventors from Japan and the European Union make up the largest shares of USPTO patents granted to foreign inventors.
- While inventors from China account for a relatively small number of USPTO patents, over the last decade, these have increased more than 10-fold. More than half of these are in electrical engineering.
- Together, biological and biomedical sciences and health sciences are major drivers of U.S. patenting activity; these are the top cited publication fields in USPTO patents across all U.S. sectors—academia, business, and federal government.
- Based on patenting across national jurisdictions, patenting activity is increasing in many parts of the world and particularly China; in 2020 inventors from China were granted almost half of all international patents.
- Electrical engineering is a strong area of invention activity with nearly half of all international patents granted to U.S. inventors in 2020 in this area.
- Coauthorship of peer-reviewed publications shows that U.S. businesses collaborate extensively with U.S. academic researchers and with foreign authors.
- Academic research and licensing of the resulting technology leads to new startup firms, which are most often founded within the state of the university producing the technology.
- Federal agencies contribute to technology transfer through licensing and research partnerships as well through the sharing of open-source software.
- Innovation rates were much higher for firms that manufacture communications equipment or publish software, where two-thirds of these firms introduced a new product or process, compared to the 27% overall rate for firms in the United States.
- Venture capital continues to spread globally, and investors from China are increasingly providing capital both in China and internationally.
- U.S. venture capital continues to flow to information technology firms, a sector that includes innovation intensive hardware, software, and communications services. This investment increased 31% from 2019 to 2020.
- Women and underrepresented demographic groups are increasing their participation in patenting and firm-level innovation.

Invention, knowledge transfer, and innovation are three interrelated concepts that form the organizing framework for assessing the U.S. and global science and engineering (S&E) enterprise in this report. Using indicators of activity and output by sector, industry, and technology area, this three-part approach highlights trends, strengths, and opportunities.

Patenting and trademark data represent early and late stages of innovation activity. Both show that these activities are geographically concentrated in the same regions of the United States, suggesting opportunities for these activities to become more broadly distributed throughout the country. Consistent with the trend of increasing internationalization, of the 354,000 utility patents awarded by the USPTO in 2020, about half were awarded to foreign inventors. Among utility patents awarded to a U.S. entity, businesses accounted for 85%, individuals for 8%, universities for 4%, and the government for 1%.

Analysis of the literature cited in patent applications provides insight into knowledge transfer across sectors, fields, and international boundaries. Peer-reviewed publications from U.S. academic institutions accounted for almost a third (31%) of the citations in USPTO patent applications to S&E literature in 2020. Furthermore, articles in biological and biomedical sciences and health sciences received the most citations, indicating that publication is a major output of these areas and that they are drivers of innovation. Additionally, U.S. business-authored publications are increasingly coauthored with U.S. academic researchers; more than half (56%) of U.S. business-authored publications share a U.S. academic coauthor. International collaboration is also increasing, with 40% of business-authored publications having one or more authors from another country. Both international collaboration and collaboration across sectors within and between countries contributes to globally important innovation activity.

Similar to publications, technology transfer represents a mechanism to evaluate the transfer of knowledge from academic and government sectors to the industry sector. Universities reported a continued increase in patenting and technology licensing activity, including through licensing to startup firms. About a fifth (19%) of the almost 8,000 new university licenses or options on licenses went to startup firms in 2019. Through the federal government, the Small Business Innovation Research (SBIR) program and its newer partner, the Small Business Technology Transfer (STTR) program, provided support to more than 4,000 firms in 2020.

Two new topic areas, citizen science and open-source software (OSS), provide insight into efforts by the federal government to promote public participation in and understanding of science and distribution of federal research output into the public sector. By engaging individuals or organizations in organized scientific projects, citizen science activities transfer knowledge to the public. In 2020, there were 268 federally supported citizen science projects. In the last decade, knowledge transfer has been increasing according to data on the use of OSS. In 2009, only the Department of Energy (DOE), the Department of Commerce (DOC), and the National Aeronautics and Space Administration (NASA) used open-source platforms to share software with other users; by 2019, 21 federal departments and agencies did so.

Innovation intensity is a measure of the share of all firms within a group that report any innovation—the release of a new product or process—within a given period. Based on data from 4.6 million firms that responded to the Annual Business Survey (ABS) regarding the introduction of a new product or process from 2015 to 2017, the software publishing industry has a high rate of innovation (66%). This greatly exceeds the average innovation intensity of 27% for all U.S. firms and is matched by two industries that are part of the manufacturing industry. Firms that manufacture communications equipment (66%) or instrumentation (64%) have similar innovation intensities to that of the software publishing industry. Chemical manufacturing also has a higher-than-average innovation intensity at 55%, which is largely driven by the innovation intensity of the pharmaceutical industry.

Firm owners reporting their ethnicity as White make up 86% of the total companies and had a 26.5% innovation intensity. Thus, innovation by firms owned by Whites largely drives the overall innovation rate of 27%. However, the innovation intensity survey data suggest that women and underrepresented minorities are making marginally more frequent contributions to innovation in business than male and White firm owners, respectively. From 2015 to 2017, majority-female-owned firms reported slightly higher innovation intensity (27.5%) compared with majority-male-owned firms (26.2%). However, these slightly higher innovation intensities have a limited impact on overall innovation intensity because majority-female-owned firms represented 21% of all firms. For the same 3-year period, 28.0% of firms whose owners reported their race as Black or African American and 28.7% of business owners who reported their ethnicity as Hispanic or Latino reported an innovation.

Although most aspects of the economy reflected pandemic-related disruptions, as indicated by newly registered trademarks in the United States, innovation activity related to COVID-19 was strong. Newly registered USPTO trademarks, which can indicate release of a new product into the market, dropped 9% from 2019 to 2020. This decline contrasts with the previous decade of consistent growth. In contrast, the swift development of COVID-19 vaccines demonstrated the value of invention and knowledge transfer based on basic research and development (R&D) to facilitate the rapid distribution of vaccines using a novel technology.

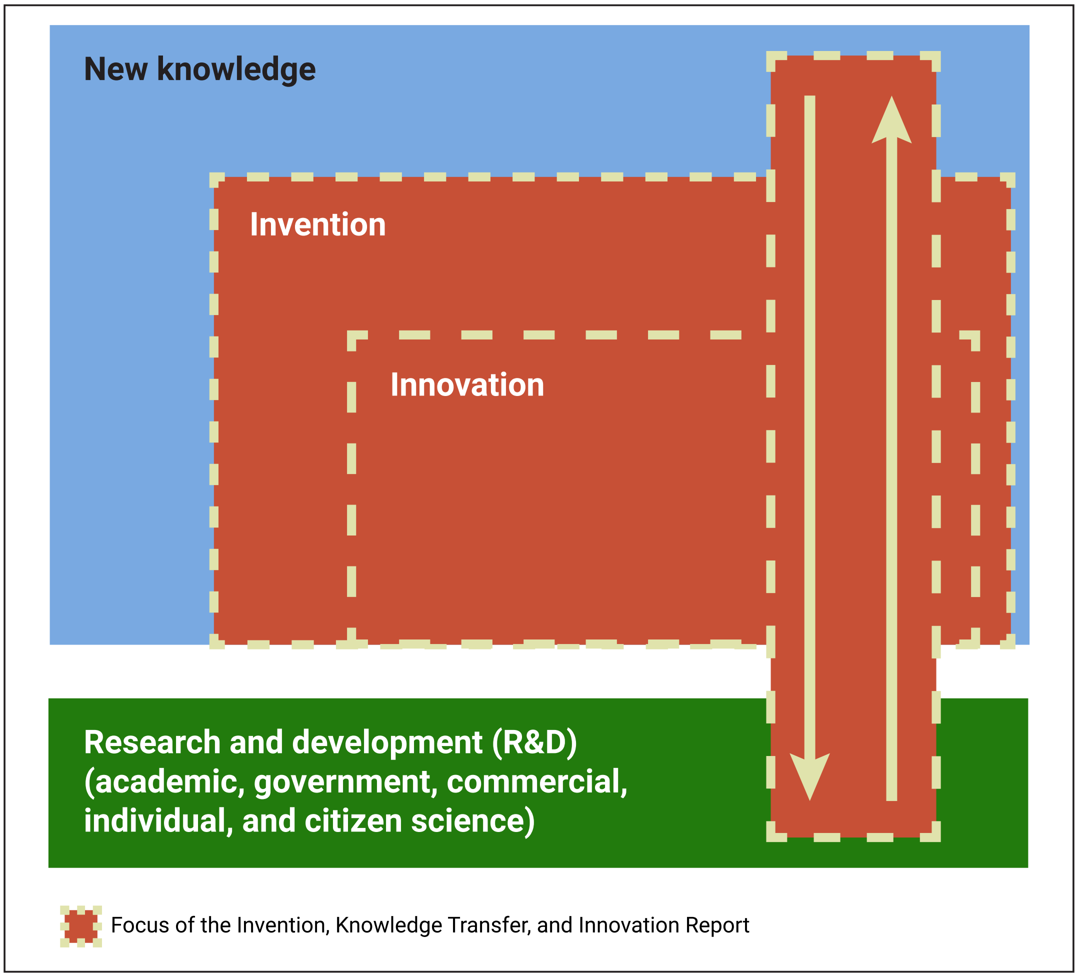
Introduction

Governments, academia, and business all contribute to the activities that comprise the innovation process. Successful business research and development (R&D) incorporates new knowledge into new products and processes while attempting to prevent useful new knowledge from spreading to rivals (Arora, Belenzon, and Sheer 2017). Governments limit release of knowledge that could compromise national security. Otherwise, governments and academia tend to create new basic knowledge with the intention of transferring the new knowledge for innovation that betters society or becomes a foundation for new products or processes in the marketplace. New knowledge created by R&D activities across all sectors takes different forms, including scientific literature meant to be published and shared and private knowledge meant to be kept secret, both of which may contribute to inventions or innovations.

In this report, inventions are defined as any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement; an invention that has been introduced into public use is an innovation. That use may be in the market or may be freely shared. The distinction between invention and innovation is an important one in the study of technological advancement. To be considered patentable, an invention must meet the additional criterion of non-obvious and useful.[1] However, the usefulness criterion requires only that an invention be useful in principle. The Organisation for Economic Co-operation and Development (OECD) distinguishes innovation from invention by defining the former as "a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)" (OECD Eurostat 2018). The term *unit* here is generic and refers to any institutional unit in any sector, including households and their individual members. Thus, the OECD's definition identifies innovations as those inventions that have achieved some degree of user impact.

These definitions identify new knowledge as a set of nested concepts (Image INV-1). All R&D output qualifies as new knowledge. A subset of this new knowledge takes the form of inventions, and a subset of inventions qualifies as innovations. Knowledge is shared among individuals, transmitted from one organization to another, and applied to new domains and fields of study. Transfer of knowledge is essential to the transformation of knowledge into new types of output. The processes by which new knowledge becomes embodied in inventions and inventions are then transformed into innovations are not linear, nor do they proceed only in one direction. Attempts to transform new scientific knowledge into invention, for example, often lead to new scientific insights. Similarly, the work required to bring new products and processes to market often leads to technology refinements that qualify as new inventions. Image INV-1 illustrates the relationship between the concepts covered in this chapter—invention, knowledge transfer, and innovation—and how they combine to push forward scientific and technological advancements.

Image INV-1



Although the definitions presented above describe invention and innovation in terms of output, both terms are also frequently used to describe the processes by which inventions and innovations are created. This report treats patents as an invention output measure and counts of trademarks and counts of companies introducing new products and processes as innovation output measures. Not all invention and innovation activity is covered in this report; good indicators are not available for many creative activities that go unmeasured. This unmeasured activity is sometimes referred to as *dark innovation* (Martin 2016).

Knowledge transfer is closely associated with invention and innovation. Technology developed at universities, for example, is rarely ready for use outside the lab without further work. Companies that license university technology usually invest significant effort in refining the new technology before introducing it to the marketplace. In this regard, the distinctions made in Image INV-1 and the divisions of this report into invention, knowledge transfer, and innovation are inherently artificial constructs.

The indicators of invention, knowledge transfer, and innovation presented in this report come from data available in public records, data collected as part of government activity, and data contained within confidential government-administered surveys (**Table INV-1**). Measurement of invention output relies heavily on patent data from the U.S. Patent and Trademark Office (USPTO) and the World Intellectual Property Organization (WIPO), as well as data regarding business approaches to intellectual property protection contained in surveys administered jointly by the U.S. Census Bureau and the National Center for Science and Engineering Statistics (NCSES). The contributions of individual inventors, separate from their activities as employees, are assessed by analysis of patents assigned to individuals.

Table INV-1

Direct and indirect indicators of invention, knowledge transfer, and innovation used in the report and their sources

(Indicator, source, and measurement type)

Section	Indicator	Source	Measurement type
Invention Indicators: Protecting Useful Ideas	Number of USPTO utility patents granted to U.S. owners by type of grantee	USPTO	Direct
	Business ranking of importance of mechanisms for intellectual property protection	NCSES U.S. Census Bureau	Direct
	Number of world patent applications, by country income group	WIPO	Direct
	Number of international patent families granted, by selected region, country, or economy	EPO	Direct
	Number of USPTO utility patents granted, by selected region, country, or economy	USPTO	Direct
	Number of USPTO patents granted to inventors in selected countries, by field of technology	USPTO	Direct
	Number of USPTO utility patents by U.S. county	USPTO	Direct
	Proportion of patent applications by country with at least one woman applicant	WIPO	Direct
Knowledge Transfer: Making Information Available	Number of coauthored business sector publications with other academic, government, and foreign institutions	USPTO Elsevier SCOPUS	Direct
	Number of citations to S&E articles in USPTO utility patents, by article field and sector of assignee	USPTO Elsevier SCOPUS	Direct
	Number of university technology licenses or license options executed, by company characteristic	AUTM	Direct
	Total number of startups launched annually based on university technology	AUTM	Direct
	Number of startups supported by federal laboratories, by selected agency	NIST Department of Commerce	Indirect
	Number of technology transfer activities supported by federal laboratories, by selected agency	NIST Department of Commerce	Direct
	Number of firms supported by SBIR and STTR programs	Small Business Administration	Indirect
	Funding in millions of dollars by SBIR and STTR programs	Small Business Administration	Indirect
	International collaborations in development of open-source software by selected country	Robbins et al. 2021	Direct
	Number of open-source GitHub repositories shared by U.S. federal departments and agencies	Robbins et al. 2021	Direct
	Number of new firms and employment from new firms (less than 1 year old)	U.S. Census Bureau	Indirect
	Number of federally sponsored citizen science projects on citizenscience.gov, by agency	citizenscience.gov	Indirect
	Number of federal citizen science projects with specific participation tasks	citizenscience.gov	Indirect
Innovation: Introducing New Products and Processes	Number of U.S. companies introducing product or process innovation, by selected industry	NCSES U.S. Census Bureau	Direct

Table INV-1

Direct and indirect indicators of invention, knowledge transfer, and innovation used in the report and their sources

(Indicator, source, and measurement type)

Section	Indicator	Source	Measurement type
	Share of U.S. companies introducing product or process innovation, by selected industry	NCSES U.S. Census Bureau	Direct
	Share of innovating businesses that are female owned	NCSES U.S. Census Bureau	Direct
	Share of innovating businesses that are non-White owned	NCSES U.S. Census Bureau	Direct
	Number of registered USPTO trademarks, by selected region, country, or economy	USPTO	Direct
	Number of U.S.-registered USPTO trademarks, by business sector	USPTO	Direct
	Number of U.S.-registered USPTO trademarks, by selected Nice classification	USPTO	Direct
	Number of USPTO trademarks by U.S. county	USPTO	Direct
	Global venture capital investment in billions of dollars, by selected country or economy	PitchBook	Indirect
	Chinese share of U.S. venture capital investment, percentage and total dollars	PitchBook	Indirect
	U.S. venture capital investment in billions of dollars, by selected industry groupings or technology areas	PitchBook	Indirect
	U.S. share of Chinese venture capital investment, percentage and total dollars	PitchBook	Indirect
	Share of firms, job creation, and employment from firms 5 years old or younger	U.S. Census Bureau	Indirect

EPO = European Patent Office; NCSES = National Center for Science and Engineering Statistics; NIST = National Institute of Standards and Technology; SBIR = Small Business Innovation Research; STTR = Small Business Technology Transfer; USPTO = U.S. Patent and Trademark Office; WIPO = World Intellectual Property Organization.

Note(s):
Direct measures use data that explicitly reflect on the rate, volume, and mix of invention and innovation outputs and knowledge transfer activities. Indirect measures are those that are correlated with these concepts but for which the linkage and impact must be inferred.

Source(s):
National Center for Science and Engineering Statistics; SRI International.

Science and Engineering Indicators

The indicators assessed in this report include both direct and indirect measures. Direct measures use data that explicitly reflect the rate, volume, and mix of invention and innovation outputs and knowledge transfer activities. Indirect measures are those that are correlated with these concepts but for which precise linkage and impact must be inferred. Patent application numbers, for example, reflect directly on invention output. Similarly, firms that cite patents as important to intellectual property protection are providing data that directly reflect their use of patents and thus their invention output. The number of total new firms started in a year, on the other hand, is an indirect measure of knowledge transfer. A share of these firms will be formed on the basis of new scientific and technical knowledge acquired from outside of the firm. Accordingly, there is a correlation between new firm formation and knowledge transfer, but the formation of a new firm does not necessarily involve knowledge transfer. The indicator thus relies on correlation rather than direct measurement.

Measures related to knowledge transfer embedded in R&D outputs include coauthorship of research publications across sectors; citations to the peer-reviewed scientific literature appearing in patents; the licensing by businesses of university-owned patents; and invention disclosure made by, patents granted to, and licenses granted by federal government entities. Knowledge transfer indicators also include measures of formal research collaboration in the form of cooperative R&D agreements between federal laboratories and one or more nonfederal organizations. In addition to these direct indicators, the report examines knowledge transfer through the lens of startup activity, including U.S. startup formation and employment trends and federal government support for startups made available through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. Indicators of innovation output rely on Annual Business Survey (ABS) data on the introduction of new products and processes, trademark registration by the USPTO, U.S. and global trends in venture capital investment, and patterns of new firm formation and employment.

The motivations to conduct R&D are diverse and include both the potential for profit as well as the desire to expand scientific knowledge. The individuals who engage in R&D and knowledge transfer are equally diverse and include staff working in commercial, government, and academic organizations as well as individual inventors and citizen scientists. As data permit, this report assesses the role and impact of contributions from academia, government, and industry, and of individuals working independently. The report also includes analyses of the geographical distribution of invention activities across the United States. Additionally, a sidebar highlights participation by citizen scientists in projects organized by federal government agencies. Finally, two additional sidebars are included. One examines open-source software (OSS) as an example of international collaboration on innovation, and the final sidebar considers how the COVID-19 pandemic has influenced innovation activities in the drive for the rapid development of vaccines.

For the first time, this report also includes three county-level machine readable public use data sets that can be downloaded to create analyses of U.S. patenting and trademarking. The patent data sets provide 23 years of county-level patent data tabulated for each of 35 technology areas based on the location of the inventor (File Supplemental Workbook INV-1) and based on the location of the patent owner (File Supplemental Workbook INV-2). The trademark dataset (File Supplemental Workbook INV-3) provides 23 years of county-level trademark data tabulated for each of 10 goods or services classifications based on the location of the trademark owner.

The major sections of the report describe the concepts of invention, knowledge transfer, and innovation in detail and present diverse indicators for each. The section on invention considers the entities that create potentially useful new products and processes, including national and international trends in invention output. The section on knowledge transfer examines the many ways in which knowledge created in one setting is refined and used in other settings, including the transfer of knowledge from universities into the commercial sector. Finally, the section on innovation examines a series of output indicators for innovation following an internationally comparable definition that has two parts: (1) an innovation is a new or improved product or process or combination of the two that differs significantly from the innovator's previous products or processes, and (2) if a product, it has been made available to potential users, and if a process, it has been brought into use (OECD Eurostat 2018).

Invention Indicators: Protecting Useful Ideas

As described in the introduction, R&D activities from all parts of society create new knowledge (Image INV-1, see Introduction). A large share of this new knowledge is intended as a public good and disclosed to the scientific community and to the public via scientific literature. This activity is described in the *Indicators* report "[2022] Publications Output: U.S. Trends and International Comparisons." A subset of new knowledge takes the form of inventions, which are the development of new and useful processes, machines, manufactures, or compositions of matter, or any new and useful improvements. Examples of invention include mechanical devices, new materials, new processes, and software programs. Inventors include researchers in government, academia, private nonprofit institutions, business firms, and individuals working independently.

The distinction between invention and innovation is important and often overlooked. Just as invention represents a subset of newly created knowledge, innovation represents a subset of invention. It is innovation that brings new products and processes into our lives. While all inventions have the potential for practical use, few are ever put to use in operational settings (Shepherd 1979). A new product or process becomes an innovation when it has been made available to potential users or brought into use (OECD Eurostat 2018). The mechanisms by which inventions are refined into innovations are complex and nonlinear, subject to feedback loops, reversals, and unforeseen, often surprising areas of application (Rosenberg 1983). A single invention can have far-reaching, multiplicative impact, not just on innovation but on further invention and scientific knowledge creation.

Governments grant exclusive rights to inventions to create incentives for organizations and individuals to conduct R&D and other activity that produces inventions and brings them into use. To qualify for the legal protection of a patent, inventions must be more than merely useful; they must also satisfy the criteria of being novel and non-obvious. Patent applications, patents granted, and citations in patent documents represent the most common set of indicators of invention. Applications are statements of potential inventions for official review, and patents granted represent official protection that is subsequently granted to that invention, after review. In this report two dimensions of patent activity are shown, patenting based on the residence of the inventor, and based on the institutional owner of the patent rights.

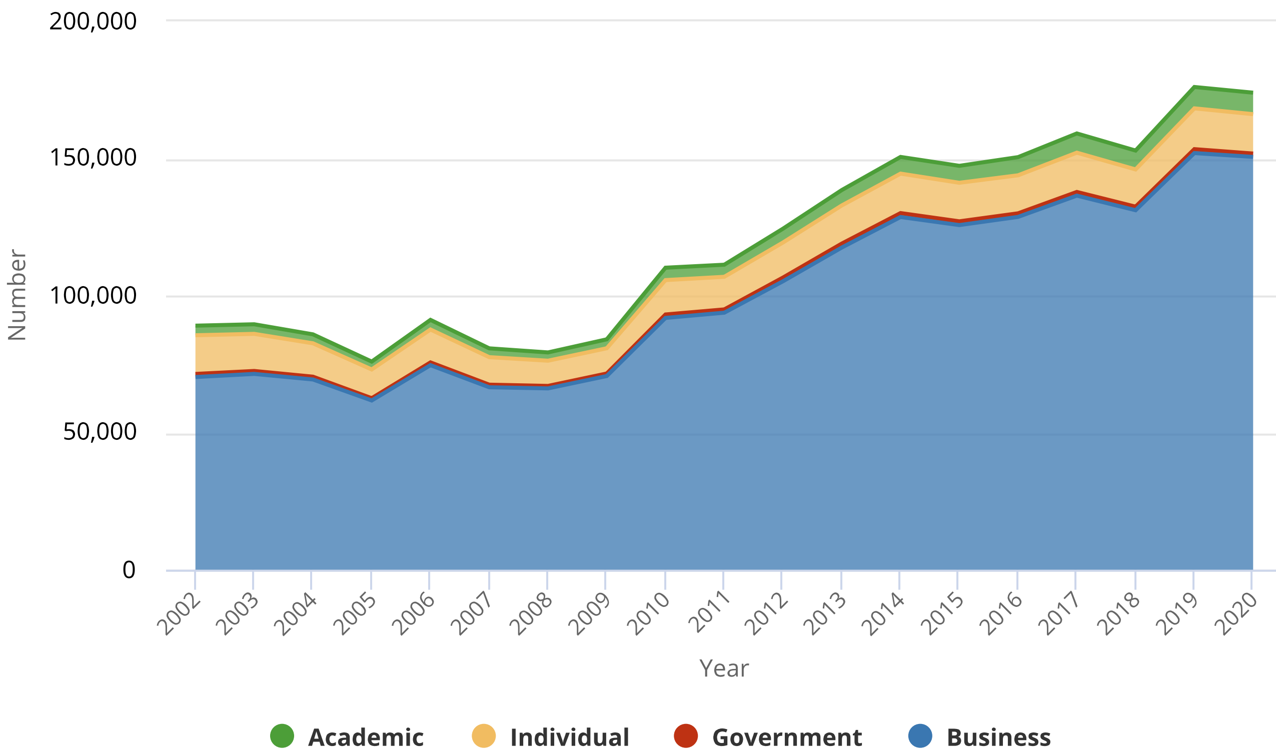
The U.S. federal government grants three types of patents: (1) design patents, which protect the visual characteristics of an invention; (2) utility patents, which protect the way that an invention functions; and (3) plant patents, which are issued for the discovery or invention of new and distinct asexually reproducing plants. In addition to patents, the U.S. Copyright Office provides for the legal protection of integrated circuit layout designs by granting mask works, which are images representing the predetermined, three-dimensional pattern of materials used to form the layers of a semiconductor chip product. Only utility patents, the largest component of patenting, are presented in this report. Trends in USPTO design and plant patents are covered in the *Indicators 2020* "**Invention, Knowledge Transfer, and Innovation**" report section "[2020] Invention: U.S. and Comparative Global Trends."

The expense associated with filing, maintaining, and defending a patent can be substantial, and patenting is not the only way that inventions are protected. In some cases, inventors do not seek patent protection because they intend for their creations to be immediately shared widely, or they choose a different form of protection. Many inventions are not patented because they do not qualify as patentable under patent law or because the disclosure required by patent applications places more information in the public domain than companies would prefer. Additionally, inventors may not consider the period of patent protection, which is 20 years from date of application, sufficient to protect their inventions. For these reasons, many commercial entities choose to protect their inventions through nondisclosure agreements and trade secrets rather than via the legal protection conferred by patenting.

Despite the many reasons inventors often do not patent their inventions, the scope of patent data available from the USPTO, the European Patent Office's PATSTAT database, and WIPO provide extensive and detailed indicators of invention, including a historical record of changing patterns of the organizations that have patented inventions. For example, although the post-World War II period in the United States has been one of dominance for business patenting and a relative decline of individual patenting, USPTO data indicate the absolute number of patents granted to individuals each year remains steadily above 10,000 patents, including 14,373 in 2020, about 8% of patents granted to U.S. owners (**Figure INV-1** and Table SINV-1).

Figure INV-1

USPTO utility patents granted to U.S. owners: 2002–20



USPTO = U.S. Patent and Trademark Office.

Note(s):
Patents are allocated according to patent ownership information. Patents are credited on a fractional-count basis (i.e., for patents with collaborating institutions, each institution receives fractional credit on the basis of the proportion of inventors from participating institutions). See Table SINV-1 for more detail.

Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2021.

Science and Engineering Indicators

USPTO, PATSTAT, and WIPO data and analysis are used in this report to examine U.S. and global trends in patenting by contributor, industry, geography, and technology area. Analysis of global trends reveals how the United States compares internationally as a source of invention. Additional data from the 2018 Business Research and Development Survey, conducted jointly by NCSES and the U.S. Census Bureau, provide indicators of the use of both patenting and trade secrets by businesses, including cross-industry differences in these indicators.

Contributors to U.S. Patent Activity

USPTO patent records provide industry, technology areas, and geographical inventor information for all patents registered in the United States, including patents granted to individuals and to foreign entities. More information on the patent data used in this report is available in the **Technical Appendix** provided with this report.

The USPTO awarded 353,701 utility patents in 2020, nearly equally divided between foreign and domestic owners (Table SINV-1). Obtaining and defending a patent incurs significant costs, and among U.S. assignees (patents that assigned the rights of ownership to a U.S. entity), businesses received by far the most patents (150,558 or 85%) (**Figure INV-1** and Table SINV-1). Utility patents assigned to individuals represented 8% of the total in 2020 (Table SINV-1). Academia received 4% of utility patent grants, and the government sector (primarily federal) received 1% of utility patents in 2020 (Table SINV-1). The persistently small contribution of the government is not surprising given that not all government labs emphasize filing patent applications for their internal research staff's discoveries; instead, federal agencies and institutions are encouraged to openly share the results of their research (Holdren 2013).

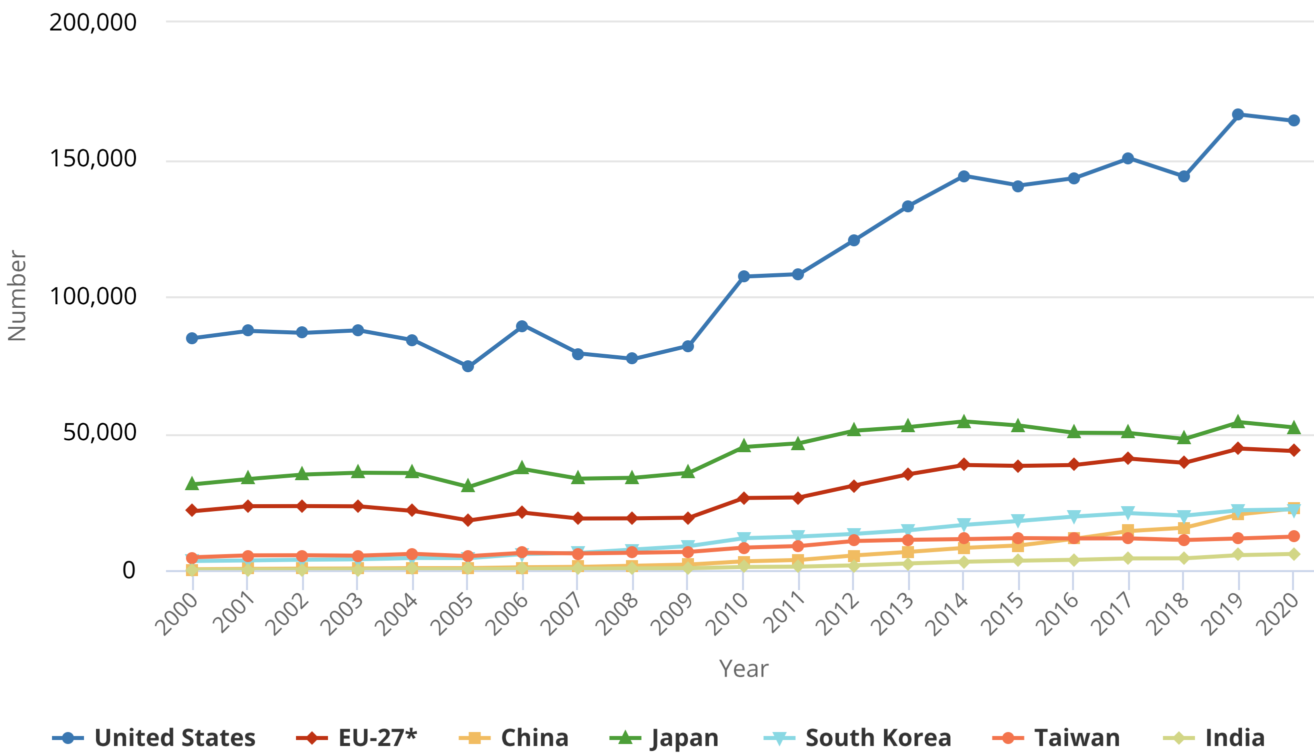
The number of patents awarded annually to U.S. patent owners dropped 1% from 2019 to 2020 after increasing 16% in the prior year. This 2020 drop is primarily accounted for by a drop in business patents. In contrast, university patents increased by almost 1% from 2019 to 2020 (Table SINV-1). The number of patents awarded to individuals also increased from 2018 to 2020; however, the share continues a long-term decline (Table SINV-1).

While international patent family data provide an illustration of global trends, USPTO patents focus on inventions, both foreign and domestic, that are granted exclusive use rights in the U.S. market. Of the 353,701 utility patents granted in 2020 by the USPTO, 164,074 were granted to U.S. inventors, or 46%. Foreign inventors were granted 54% in 2020, up from 46% in 2000, continuing the trend of increased internationalization of U.S. patents (Table SINV-44).

Large multinational companies, including those based outside of the United States, have increasingly sought patent protection beyond their domestic borders. As commercial activities increasingly cross international borders, rising rates of foreign patenting reflect, among other factors, the desire of foreign firms to seek patent protection in multiple international jurisdictions (Fink, Khan, and Zhou 2015). The European Union (EU) and Japan continue to account for the largest numbers of foreign USPTO patent grantees (**Figure INV-2**). Although inventors from China account for a relatively small number of USPTO patents, over the last decade, these have increased more than 10-fold from 1,606 in 2008 to 22,500 in 2020 (**Figure INV-2**). Patents related to electrical engineering accounted for the majority (63%) of USPTO patents granted to inventors from China (**Figure INV-3**).

Figure INV-2

USPTO utility patents granted, by selected region, country, or economy: 2000–20



EU = European Union; USPTO = U.S. Patent and Trademark Office.

*Beginning in 2020, the United Kingdom was no longer a member of the EU.

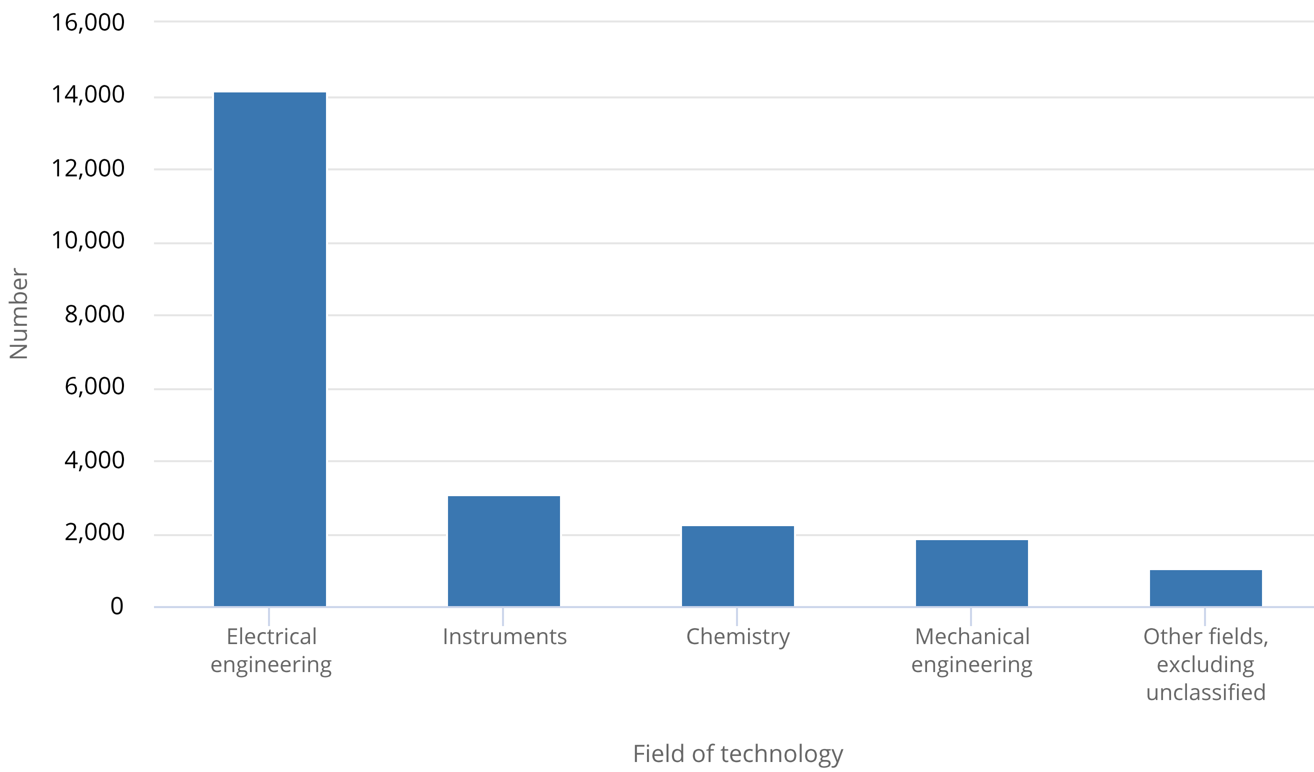
Note(s):
Patents are allocated according to patent inventorship information. Patents are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named inventors. China includes Hong Kong. See Table SINV-44 for additional countries.

Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2021.

Science and Engineering Indicators

Figure INV-3

USPTO patents granted to inventors from China, by field of technology: 2020



USPTO = U.S. Patent and Trademark Office.

Note(s):
Civil engineering is included in Other fields. Patents are allocated geographically according to patent inventorship information. They are classified technologically under the World Intellectual Property Organization classification that is made up of 35 International Patent Classification technical fields. Fractional counts of patents to each technological field assign the weight of a patent to the corresponding technological fields. For instance, a patent that is classified under five different technological fields will contribute 0.2 patent counts to each of its technological fields. Data across technical fields also sum up to the total number of USPTO-granted patents. See Table SINV-4 for more information on fields of technology. See Table SINV-45 through Table SINV-80 for data by technical field.

Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2021.

Science and Engineering Indicators

According to a recent USPTO report, the growth in USPTO patents granted to China is driven by both market forces and nonmarket factors. University and government subsidies for patenting can exceed the cost of filing the patent and these subsidies are often higher for patents granted in foreign jurisdictions (USPTO 2021a).

To accelerate the patent approval process for inventions related to COVID-19 that are also subject to Food and Drug Administration approval, the USPTO instituted a program early in 2020 that would allow for prioritized examination without an additional prioritization fee. As of August 2021, 120 patents have been issued under the pilot program (USPTO 2021b).

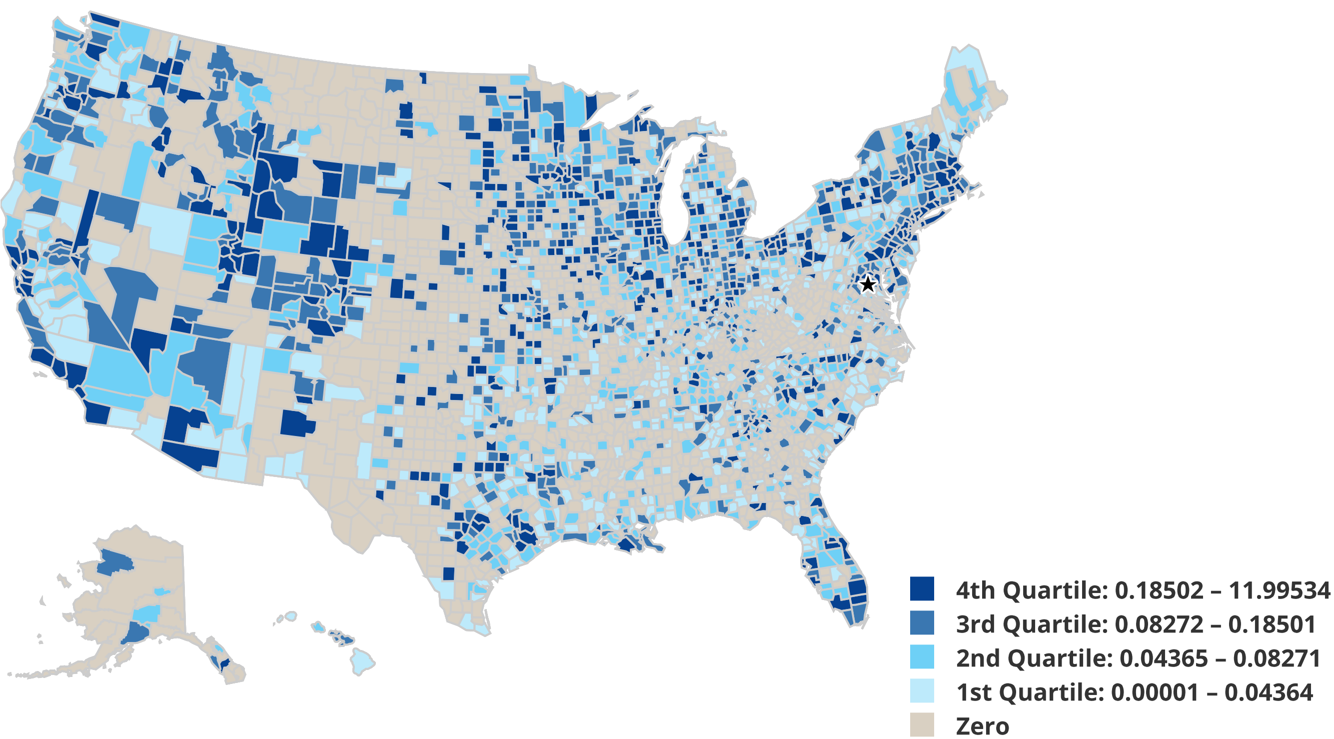
The Geography of U.S. Patenting

As a market-driven activity, invention tends to take place where skilled human capital and other inputs are relatively abundant and low cost. As new knowledge spreads, it produces growth benefits or spillovers with a localized dimension that drive additional growth (Grossman and Helpman 1991). States that have relatively high proportions of workers with a bachelor's degree or higher in science, technology, engineering, and mathematics (STEM) are located primarily on the east and west coasts of the United States and in the Midwest (see *Indicators* report "[2022] The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers"). As skilled labor and other inputs accumulate, the result can be that a location's initial advantages grow over time relative to other locations, leading to different growth rates and economic outcomes. Patenting provides an indicator of the location of inventive activity.

County-level patenting intensity is measured here by the location of the owner of the patents granted per 1,000 population in 2020;[2] counties with high patenting intensity are concentrated in the United States along the coasts and in parts of the Great Lakes region, Texas, and the Rocky Mountains (**Figure INV-4**). This geographic distribution corresponds with indicators of knowledge- and technology-intensive (KTI) industries, in which California is the single largest producer of KTI industry output, followed by Texas and New York (see forthcoming *Indicators* report "[2022] Production and Trade of Knowledge- and Technology-Intensive Industries").

Figure INV-4

USPTO utility patents granted to U.S. owners per 1,000 residents, by U.S. county: 2020



USPTO = U.S. Patent and Trademark Office.

Note(s):
USPTO patents are allocated according to ownership information. U.S. addresses were geocoded to 3,143 U.S. counties according to U.S. states, U.S. cities, and zip codes appearing in these addresses. Because of the absence of zip codes for most U.S. addresses in the patent data, co-assignment to multiple U.S. counties occurred for addresses accounting for about 14% of all U.S. patent counts, mostly in populous cities encompassing multiple counties. This may lead to some underestimation or overestimation of patent output for some counties within these cities. Further manual disambiguation was performed based on information available to assign some of the ambiguous addresses to a single county. When more than one county remained for an address on a patent, the fraction of the patent associated to this address was split equally across all of the counties. Patents are classified under the World Intellectual Property Organization (WIPO) classification of patents, which classifies

International Patent Classification (IPC) codes under 35 technical fields. IPC reformed codes take into account changes that were made to the WIPO classification in 2006 under the eighth version of the classification and were used to prepare these data. However, because PatentsView only provides the original IPC codes as they appeared on patents and not the IPC reformed codes, current Cooperative Patent Classification codes on patents were converted back to the most recent IPC classification to prepare these statistics. Fractional counts of patents were assigned to each technological field on patents to assign the proper weight of a patent to the corresponding technological fields under the classification. See File Supplemental Workbook INV-2 for additional detail.

Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2021; Population data from the U.S. Census Bureau accessed June 2021 at https://www.census.gov/newsroom/press-releases/2021/2020-vintage-population-estimates.html.

Science and Engineering Indicators

The county patenting data files released with this report provide additional detail by technology area, showing, for example, the high rate of patenting in transportation technology in Oakland and Wayne Counties in Michigan (File Supplemental Workbook INV-2). Industry output data at the state level show that Michigan's output has a high degree of specialization in the KTI industry of motor vehicle production (see forthcoming *Indicators* report "[2022] Production and Trade of Knowledge- and Technology-Intensive Industries").

In 2020, 41.6% of counties had zero patents granted to owners in that county. A patent count of less than one can occur when there are two or more county addresses on the patent. The patent is treated as a fraction in this case and divided across the relevant counties. The top three counties in 2020 for patenting intensity are Santa Clara in California, followed by Schenectady and Westchester Counties in New York (**Figure INV-4**).

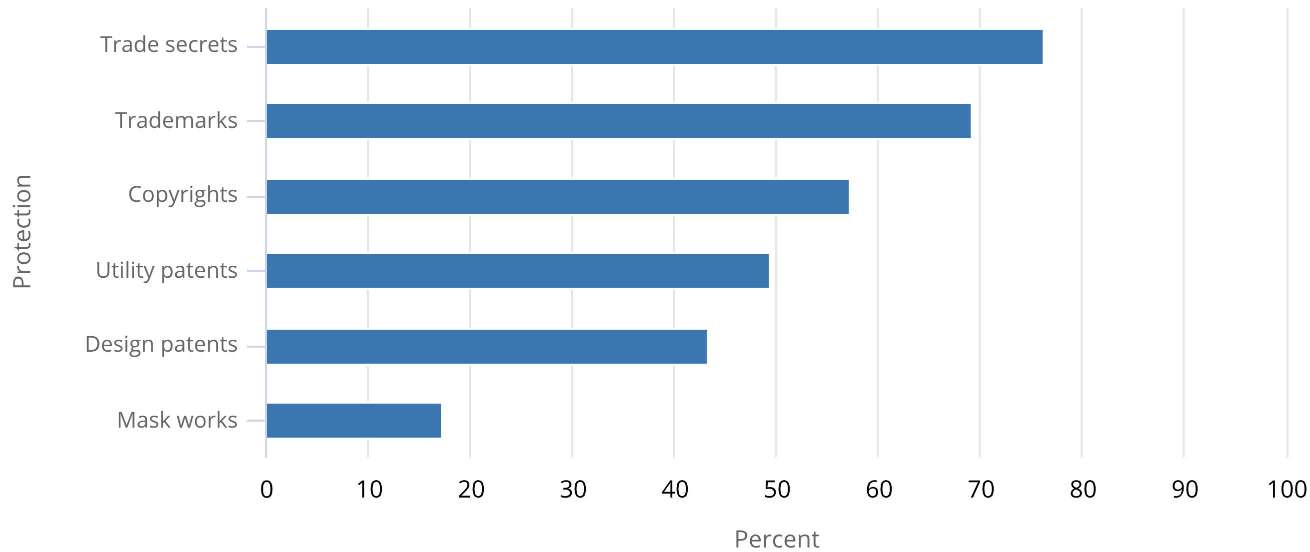
Patenting in Context: U.S. Businesses Use a Variety of Intellectual Property Protections

The detailed geographic analyses possible with patent data represent just a portion of all the ways that economically valuable ideas and inventions are protected by their owners. Nondisclosure agreements, trade secrets, trademarks, and copyrights are used by U.S. businesses in addition to utility and design patents (Shackelford and Kindlon 2021).

Business survey data for 2018 show that almost half (49%) of businesses with 10 or more employees rated utility patents as either very or somewhat important (**Figure INV-5**). Trade secrets were important for just over three-quarters (76%) of these businesses (**Figure INV-5**).

Figure INV-5

Rating of importance of different types of intellectual property protections by U.S. companies that performed or funded R&D: 2018



Note(s):
"Important" is the sum of two columns of response, very important and somewhat important. The Business Research and Development Survey does not include companies with fewer than 10 domestic employees.

Source(s):
National Center for Science and Engineering Statistics and U.S. Census Bureau, Business Research and Development Survey, 2018.

Science and Engineering Indicators

The importance of patenting varies widely across the U.S. industries that perform or fund R&D. The industries that place the highest importance on patenting include utilities (77%) and mining, quarrying, and oil and gas extraction (76%) (**Figure INV-6**). Across each of the industries analyzed, trade secrets were rated as more important than patents, although for the utilities and mining industries, the difference was minor. The relative importance of trade secrets was highest in finance and insurance, in which 70% of businesses rated trade secrets as important, while only 19% of businesses rated patents as important (**Figure INV-6**). Among electronic shopping and auctions businesses, an additional 48% of businesses rated trade secrets important than rated patents important (**Figure INV-6**).

Figure INV-6

R&D performing or funding U.S. companies that rate intellectual property protection as important, by intellectual property type and industry: 2018

Note(s):
"Important" is the sum of two columns of response, "very important" and "somewhat important."

Source(s):
National Center for Science and Engineering Statistics and U.S. Census Bureau, Business Research and Development Survey, 2018.

Science and Engineering Indicators

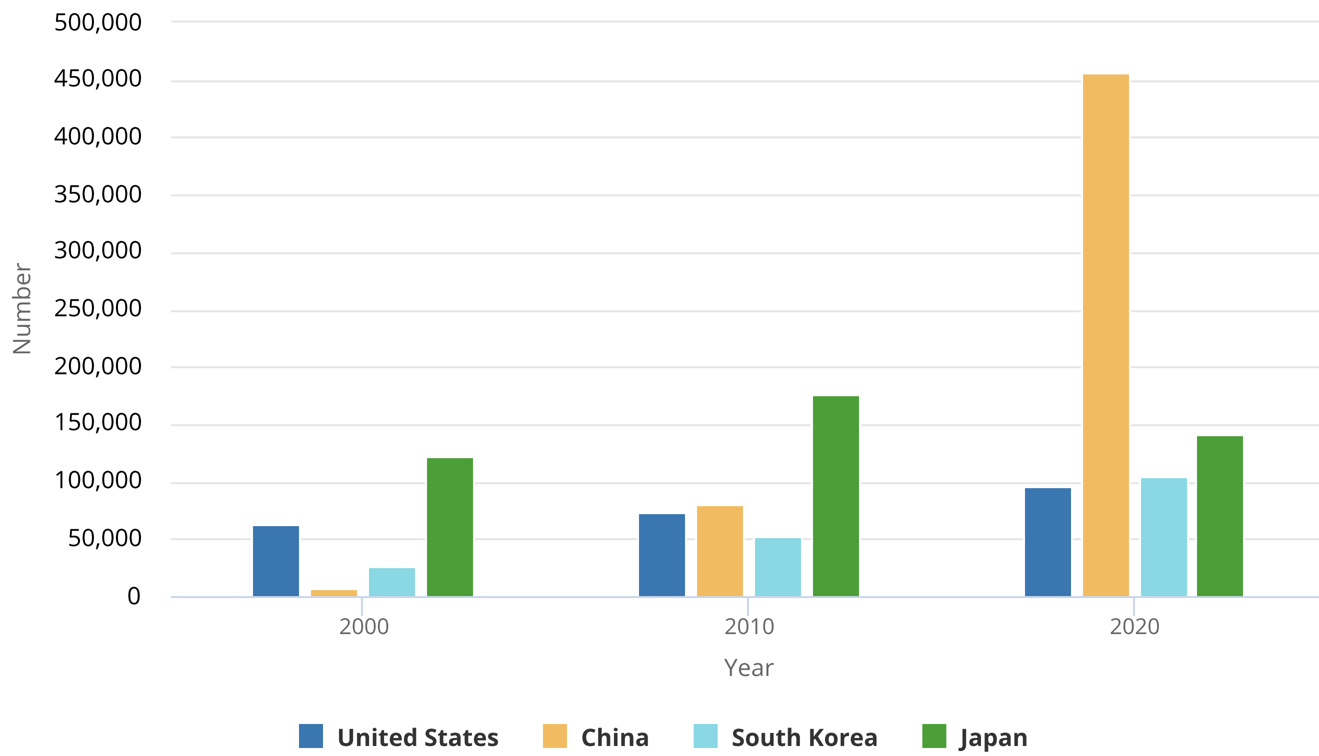
Global Trends in Patenting Activity

In contrast to the U.S.-focused data from the USPTO, this section presents global patenting trends through patents granted in international jurisdictions. International patents, as described in this section are an unduplicated count of original or priority patents in any individual jurisdiction. The unit of measurement is a patent *family* that shares a single original invention in common. All subsequent patents in a family refer to the first patent filed, called the priority patent. One patent family consists of all of the patents granted for the same invention in at least one patent jurisdiction, based on the priority date. They represent a broad measure of international trends in inventive activity that prevents double counting when an invention is registered in multiple jurisdictions. The underlying data are prepared based on the International Patent Documentation from the European Patent Office’s Worldwide Patent Statistical Database, adjusted to account for jurisdictional differences in registering provisional patents.[3]

On this basis, there were 938,038 international patents granted in 2020. U.S. inventors accounted for 95,347 (10%) in 2020, up from 73,622 in 2010 (**Figure INV-7**). In comparison, the number of USPTO patents registered to U.S. inventors was greater, at 164,074 patents (Table SINV-44). Based on the international patent family counting, these 95,347 international patents are an indicator of the birth of a new patent family, based on an original priority patent.

Figure INV-7

International patent families granted, by country: 2000, 2010, and 2020



Note(s):
International Patent Documentation (INPADOC) patent families across all patent offices covered in the Worldwide Patent Statistical Database (PATSTAT) are counted according to the year of the first granted patent in the patent family. Patent families are allocated according to patent inventorship information found on the priority patent of the INPADOC families. To account for missing ownership information in PATSTAT for some offices, a method designed by de Rassenfosse et al. (2013) is used to fill missing information on priority patents using information in successive filings within the families. Priority patents not indexed in PATSTAT are replaced by the next utility patent(s) in the families according to filing dates. Patent families are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named inventors. China includes Hong Kong. See Table SINV-5 for additional countries.

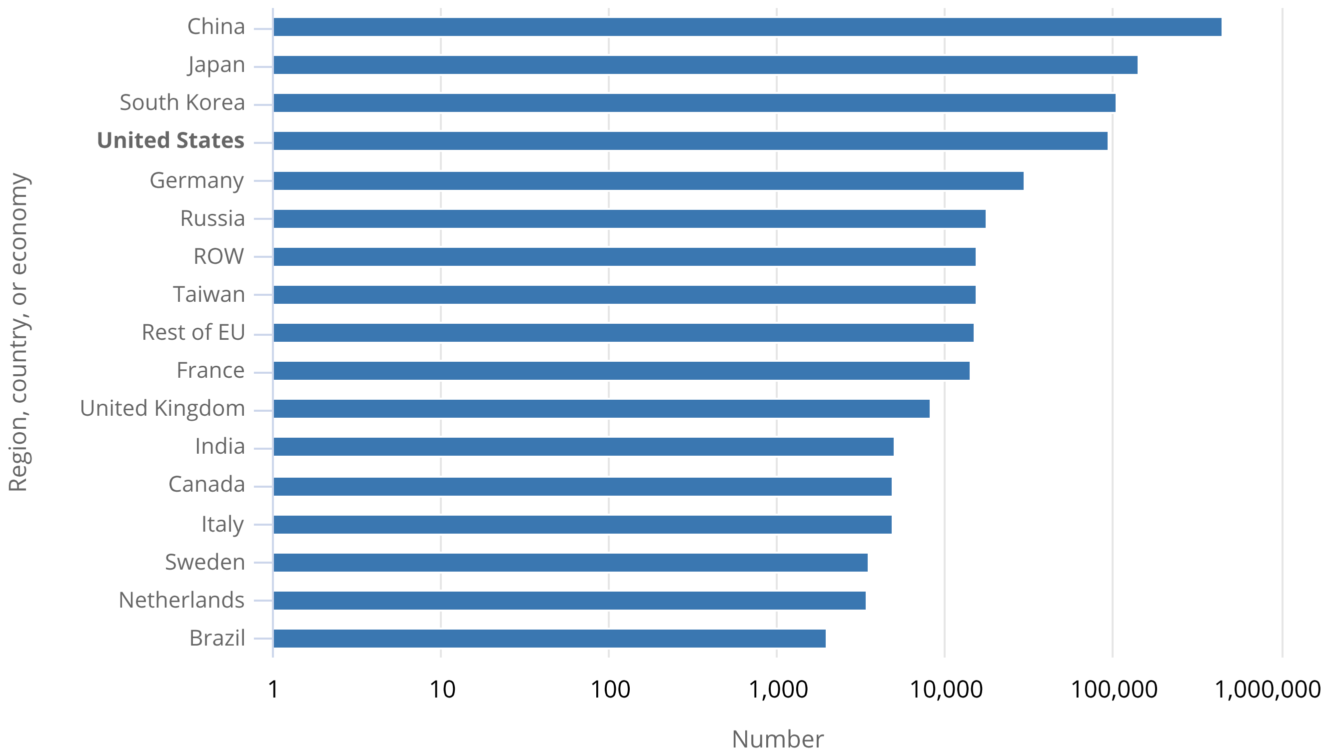
Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; PATSTAT, accessed October 2021.

Science and Engineering Indicators

By this broad measure, new patent family activity is currently centered in Asia. Inventors from Japan had the highest number of patents granted in 2000 and 2010; however, the number of patents granted to Japanese inventors started declining in 2014. By 2020, inventors from China made up the largest number, with about 456,000, accounting for nearly half (49%) of the patents granted in 2020 (**Figure INV-7**). Inventors from two of China's high-income neighbors accounted for large numbers of international patents granted; 141,286 international patents were granted in Japan and 104,490 in South Korea (**Figure INV-8**).

Figure INV-8

Log scale of international patent families granted, by region, country, or economy: 2020



EU = European Union; ROW = rest of world.

Note(s):
World total equals 938,038. International Patent Documentation (INPADOC) patent families across all patent offices covered in the Worldwide Patent Statistical Database (PATSTAT) are counted according to the year of the first granted patent in the patent family. Patent families are allocated according to patent inventorship information found on the priority patent of the INPADOC families. To account for missing ownership information in PATSTAT for some offices, a method designed by de Rassenfosse et al. (2013) is used to fill missing information on priority patents using information in successive filings within the families. Patent families are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named inventors. China includes Hong Kong. See Table SINV-5 for additional countries.

Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; PATSTAT, accessed June 2021.

Science and Engineering Indicators

While historically patenting has been an activity of high-income countries, rapid growth in patents from China have changed this dynamic. China is not the only middle-income country of the top 15 locations where international patents are registered. Russia and India are also considered middle-income countries and in the top 15 locations with the highest number of international patents granted in 2020 (Table SINV-5). India, with more than 5,000 patents in 2020, is the only lower middle-income country in the top 15 (Table SINV-5). Patents granted to inventors in Brazil, an upper middle-income country, increased nearly twentyfold from 2000 to 2020, reaching more than 2,000 patents in 2020. It is now the 18th-highest patenting country.

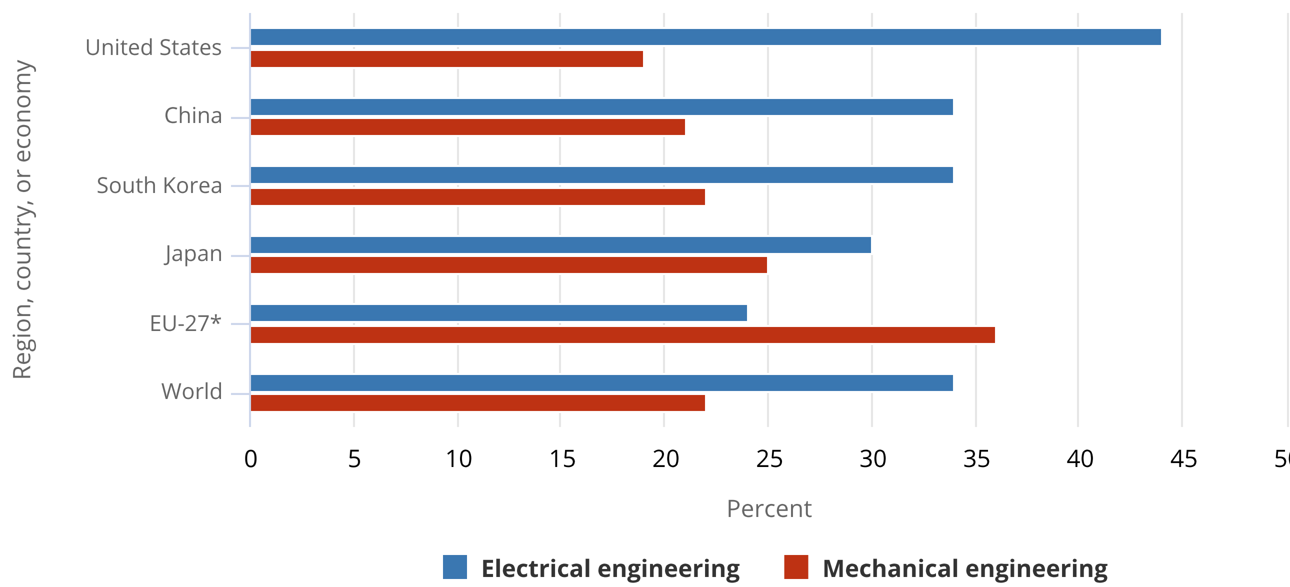
Technology fields within patent documents allow comparisons across countries at both a broad and detailed level (Table SINV-4 through Table SINV-41). The 35 detailed categories aggregate into five broad technology areas: electrical engineering with 34% of patents (317,611), mechanical engineering with 22% (208,560), chemistry with 19% (176,693), and instruments with 16% (148,131). Other fields accounted for 9% (82,036) in 2020.

Based on technology areas, within electrical engineering patents, information technology management patents increased at the fastest rate, 35%, from 2019 to 2020 (Table SINV-12). Six other detailed categories increased 15% or more from 2019 to 2020: patents in computer technology (Table SINV-11), also an electrical engineering area; the categories of macromolecular chemistry and polymers, basic materials, and chemical engineering within chemistry patents (Table SINV-22, Table SINV-24, and Table SINV-28, respectively); and other special machines within mechanical engineering (Table SINV-34).

Electrical engineering patents are an area of relative strength for U.S. inventors. Electrical engineering made up close to half (44%) of international patents awarded to U.S. inventors in 2020, compared with 34% for inventors from all locations. Inventors in the EU produced a larger share of mechanical engineering patents (**Figure INV-9**).

Figure INV-9

Share of electrical and mechanical engineering patents in a selected region's, country's, or economy's international patent families granted: 2020



EU = European Union.

*Beginning in 2020, the United Kingdom was no longer a member of the EU.

Note(s):
International Patent Documentation (INPADOC) patent families across all patent offices covered in the Worldwide Patent Statistical Database (PATSTAT) are counted according to the year of the first granted patent in the patent family. Patent families are allocated according to patent inventorship information found on the priority patent of the INPADOC families. To account for missing ownership information in PATSTAT for some offices, a method designed by de Rassenfosse et al. (2013) is used to fill missing information on priority patents using information in successive filings within the families. Priority patents not indexed in PATSTAT are replaced by the next utility patent(s) in the families according to filing dates. Patent families are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named inventors. China includes Hong Kong. The electrical and mechanical engineering fields of technology are defined using the World Intellectual Property Organization classification of patents. See Table SINV-4 for more information on fields of technology. See Table SINV-6 through Table SINV-13 and Table SINV-30 through Table SINV-37 for data by technical field.

Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; PATSTAT, accessed October 2021.

Science and Engineering Indicators

Tabulated data for each of the 35 technology areas by country and year (Table SINV-4 through Table SINV-41) and for U.S. inventors by technology area and year (Table SINV-42 and Table SINV-43) are provided in Supplemental Tables.

Characteristics of Patented Inventors

Patenting activity is unevenly distributed among men and women, with men much more likely to be named as inventors on patents issued, according to recent analyses by the USPTO and WIPO. While the two analyses used different datasets and different measures of patenting and participation, both found underrepresentation of women named as inventors in patent documents (USPTO Office of the Chief Economist 2020; WIPO 2020b).

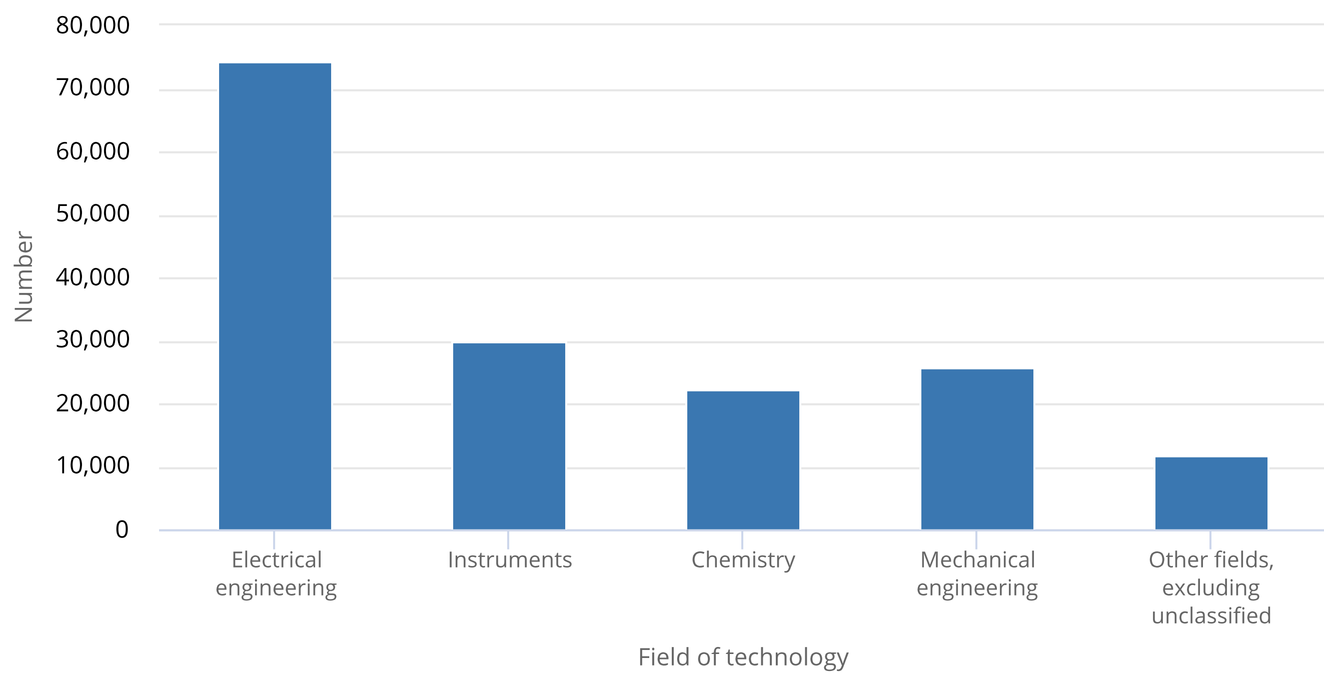
One way to see trends in inventorship by women is based on the number of patents with at least one woman named as an inventor. The patent team may have one woman or twenty, and the count would be the same number. This number divided by the total number of patents issued in that year is an indicator of the share of patents with at least one woman named as an inventor. For patents granted by the USPTO in each year, this share was 22% in 2019, a share that increased from under 5% in 1976 (USPTO Office of the Chief Economist 2020).

Another useful ratio is the women inventor rate (WIR), which is the number of women named as inventors on all patents issued divided by the number of all named inventors for a given period. This ratio is a somewhat broader way to measure changes in the participation of women as patented inventors. By this measure, the WIR was 12.8% for 2019 (USPTO Office of the Chief Economist 2020).

To put the sex imbalance in context, patents in electrical and mechanical engineering made up 61% of all USPTO patents granted to U.S. inventors in 2020 (**Figure INV-10**). As two of the thematic reports in *Indicators 2022* describe, engineering is an area in which women are underrepresented in the United States. In 2019, women received about a quarter of bachelor's degrees and doctoral degrees in engineering and held about a quarter of the postdoc positions in engineering (see *Indicators* report "[2022] Higher Education in Science and Engineering" and *Indicators* report "[2022] The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers").

Figure INV-10

USPTO patents granted to U.S. inventors, by field of technology: 2020



USPTO = U.S. Patent and Trademark Office.

Note(s):
Civil engineering is included in Other fields. Patents are allocated geographically according to patent inventorship information. They are classified technologically under the World Intellectual Property Organization (WIPO) classification that is made up of 35 International Patent Classification (IPC) technical fields. Fractional counts of patents to each technological field assign the weight of a patent to the corresponding technological fields. For instance, a patent that is classified under five different technological fields will contribute 0.2 patent counts to each of its technological fields. Data across technical fields also sum up to the total number of USPTO-granted patents. See Table SINV-4 for more information on fields of technology. See Table SINV-45 through Table SINV-80 for data by technical field.

Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2021.

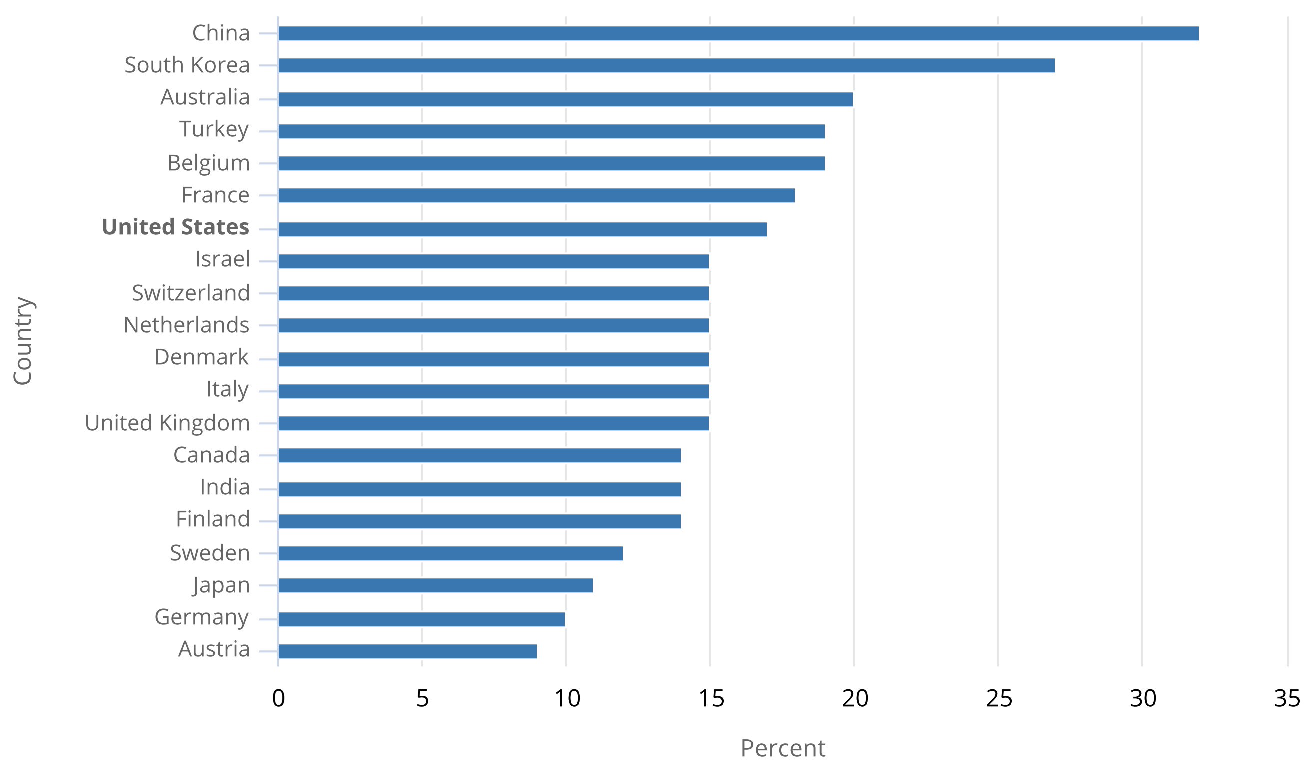
Science and Engineering Indicators

However, as the USPTO report points out, women participate in all science occupations at a much higher rate than they invent patented technology, suggesting that increasing the numbers of women in science and engineering jobs alone will not bring parity in the number of women as inventor-patentees (USPTO Office of the Chief Economist 2020).

Internationally, WIPO has analyzed the representation of women in patenting, finding substantial variations across countries (WIPO 2020b).[4] For the 20 patent offices with the highest numbers of patenting activity, WIPO found that based on applications registered through WIPO's Patent Cooperation Treaty (PCT), the share of patent applications with at least one woman was highest for China (32%) and South Korea (27%) (**Figure INV-11**). In contrast, only 17% of the PCT applications from the United States had a woman listed as an inventor.

Figure INV-11

Share of PCT applications with at least one woman listed as inventor for the top 20 origins: 2019



PCT = Patent Cooperation Treaty.

Note(s):
In order to attribute sex to inventors' names recorded in PCT applications, the World Intellectual Property Organization (WIPO) produced a sex–name dictionary based on information from 13 different public sources. Sex is attributed to a given name on a country-by-country basis because certain names can be considered male in one country but female in another.

Source(s):
WIPO Statistics Database and Worldwide Patent Statistical Database (PATSTAT) database, September 2020, accessed March 2021.

Science and Engineering Indicators

The likelihood of patenting is linked to family income and education, as well as the sex of the individual. By linking USPTO patent data to the income of individuals (or households) through confidential tax records, an analysis over time of 1.2 million U.S. inventors found that those who were from high-income families as children are 10 times more likely to become inventors than those who were from below median-income families as children. The same analysis found U.S. men were more likely to invent than U.S. women (Bell et al. 2018).

Knowledge Transfer Indicators: Making Information Available

As described in the previous **Invention Indicators: Protecting Useful Ideas** section, the output of R&D, both formal and informal, includes scientific knowledge, inventions (i.e., new and useful processes, machines, manufactures, or compositions of matter, or any new and useful improvements thereof), and innovations, which are new products or processes that have been made available to potential users or brought into use (OECD Eurostat 2018). Knowledge transfer is broader and more diverse. It encompasses the many activities whereby newly created knowledge is shared with those who can apply it, develop it, or transform it into new outputs, inventions, and innovations. The institutional performers of R&D activity are covered in detail in the forthcoming *Indicators* report "[2022] Research and Development: U.S. Trends and International Comparisons" and the *Indicators* report "[2022] Academic Research and Development." Knowledge transfer also includes transfer between individuals, transfer from one organization to another, and transfer to new fields of study and domains of application.

The transformative role of knowledge transfer is illustrated in Image INV-1 (see **Introduction** section). The processes by which knowledge becomes embodied in new inventions, and inventions are transformed into innovations, are nonlinear and proceed through multiple directions. New insights on the natural world emerge from successful and unsuccessful attempts to transform new scientific knowledge into inventions. Similarly, the work required to bring new products and processes to market often leads to refinements that themselves qualify as new inventions.

Knowledge embedded in technology constitutes a special case of knowledge transfer often referred to as technology transfer. Indicators discussed in this chapter include both the narrower case of technology transfer and the broader category of knowledge transfer. Although businesses conduct the largest share of U.S. R&D, academic institutions and federal labs are also key contributors to knowledge creation (see forthcoming *Indicators* report "[2022] Research and Development: U.S. Trends and International Comparisons") and knowledge transfer.

Both formal R&D and informal activities conducted by organizations and individuals produce new knowledge. That knowledge can be transferred through the dissemination of the information embedded in documented R&D outputs, such as publications, patents, and software; through direct organization-to-organization interaction and collaboration; and via direct and tacit interaction among individuals. Most knowledge transfer indicators described in this report directly measure the operation of these transfer mechanisms. Coauthorship of research publications across business, academia, and government is used to assess the transfer of knowledge across sectors. Citations to the peer-reviewed scientific literature appearing in patents provide evidence of the application of scientific knowledge to invention and highlight knowledge transfer between universities and businesses.

In addition to its contribution to indicators based on published research, the role of academia in knowledge transfer is assessed via the licensing by businesses of university-owned patents. Several indicators highlight the role of the federal government in knowledge transfer. These include: (1) invention disclosures made by, patents granted to, and licenses granted by federal government entities; (2) cooperative R&D agreements between federal laboratories and one or more nonfederal organizations; and (3) the open-source licensing of software created for government use.[5]

Startup companies that form based on the licensing of university technology represent a particularly important form of knowledge transfer: they signal the active commercial use of new knowledge and overlap with those described above. In addition to the formal licensed use of technology, knowledge transfer can play an indirect role as startups draw on newly created knowledge to provide the basis for their commercial activities. Indicators related to startups include general U.S. startup formation and employment trends and financial support of startups through the SBIR and STTR programs.

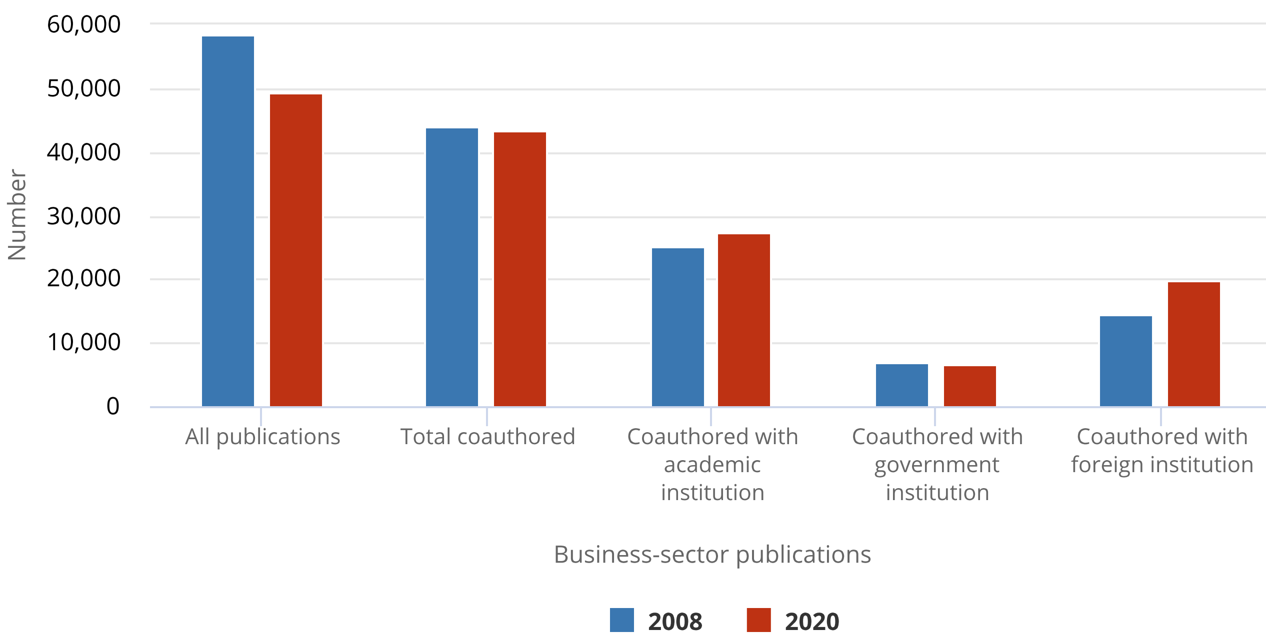
Business Collaborations in Published Literature

All parties benefit when business, academia, and government agencies collaborate. Through collaboration, the participants gain access to advanced tools, emerging technologies, unpublished or private data, and technical expertise. An indicator of such collaborations is the authorship data of peer-reviewed publications in the Scopus database. Scopus is an abstract and citation database of scholarly literature provided by Elsevier Publishing. Peer-reviewed publications by business authors have become more collaborative over time, although fewer in number. One indication of the high impact of collaborations on the progress of science and engineering (S&E) is the greater than average citation of articles with authors from multiple sectors versus those with authors from a single sector or institution (Shneiderman 2018).

Authors with U.S. business affiliations published 49,000 peer-reviewed publications in 2020, based on the Scopus publications output data reported in the *Indicators* report “[2022] Publications Output: U.S. Trends and International Comparisons.” The total number of peer-reviewed publications in that year with a U.S. address was almost half a million (456,000). Almost 90% (43,203) of business-authored publications were coauthored with authors from other institutions, including other businesses, up from 75% in 2008 (**Figure INV-12**). Business-authored publications are increasingly coauthored with U.S. academic researchers, the share increasing from 43% (25,112) in 2008 to 56% (27,475) in 2020 (**Figure INV-12**). Collaboration between the federal government and business represent a relatively small portion of the coauthored publications in 2020 at 13% (6,563) (**Figure INV-12**).

Figure INV-12

Coauthored business-sector publications with other academic, government, and foreign institutions: 2008 and 2020



Note(s):
Publications are classified by their publication year and are assigned to a sector based on the institutional address(es) listed within the author information. Each publication is credited to a sector based on the institution type. Each collaborating institution is credited as coauthoring in this table when the listed authors come from different sectors. The publication is counted as one count in the sector (whole counting). Publications can be authored by collaborators in multiple sectors, thus the sum of publications coauthored with various sectors can exceed the total. Publications from unknown U.S. sectors are not shown.

Source(s):
National Center for Science and Engineering Statistics; Elsevier; Scopus abstract and citation database, tabulated by Science-Metrix, May 2021.

Science and Engineering Indicators

Business-authored publications are also increasingly coauthored with international authors, a trend reflected in the overall increase of international collaboration in peer-reviewed literature (NSB 2021a). Among the business-coauthored publications, this category of cooperation grew the most. From 2008 to 2020, the number and proportion of publications coauthored between U.S. businesses and foreign collaborators increased, reaching 40% (19,884) in 2020 (**Figure INV-12**). Publications, citations, and collaborations in peer-reviewed literature are covered in greater depth in the *Indicators* report "[2022] Publications Output: U.S. Trends and International Comparisons."

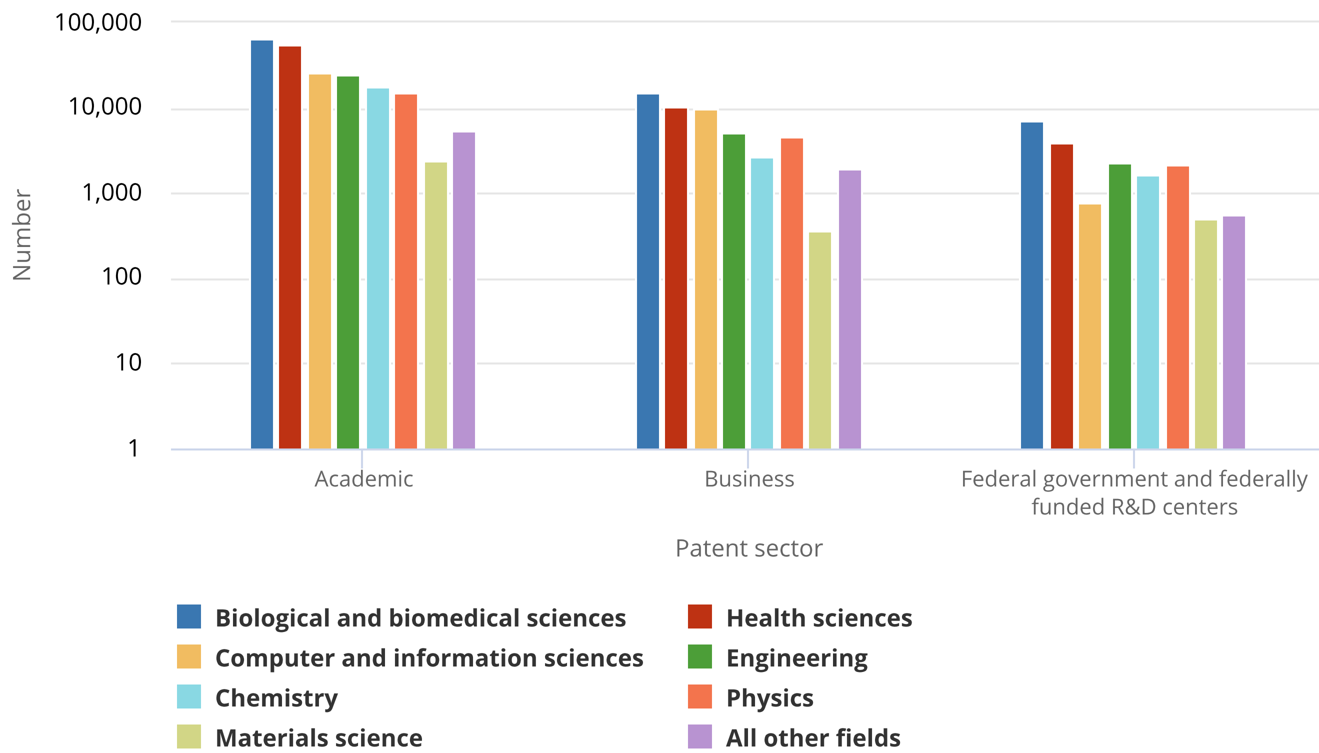
Publications Cited in Patents

When peer-reviewed publications like those described above are cited in patent documents, the linkage between the two documents provides an indicator of knowledge transfer from the scientific literature to the patent. These indicators show the disproportionately large role of academic publications in patent citations, pointing to the importance of academic research in invention. Data for peer-reviewed publications are from the Scopus database used in the *Indicators* report "[2022] Publications Output: U.S. Trends and International Comparisons." The same taxonomy of disciplines for fields of science and classification of sectors that produce publications from that report are used here.

Biological and biomedical sciences are most often cited in patent documents; this is true for U.S. authors affiliated with academia, business, or federal labs (**Figure INV-13**). However, the scale of these citations varies substantially. Authors from academia contributed the greatest number and proportion of S&E articles cited in patents in 2020. Of the 696,000 citations to S&E articles in patents in 2020, about 31% (214,305) were to articles from the U.S. academic sector (Table SINV-82). Publications of U.S. S&E articles with academic-affiliated authors in the biological and biomedical sciences received 66,000 citations in patent documents, publications with business-affiliated authors received 15,000 citations, and publications with federal government-affiliated authors received almost 7,000 (**Figure INV-13**).[6] Health sciences publications, the next most cited category for each sector, was the field with the largest number of publications worldwide in 2020 according to the analysis of all S&E articles in the *Indicators* report "[2022] Publications Output: U.S. Trends and International Comparisons."

Figure INV-13

Log scale of citations of U.S. S&E articles in USPTO utility patents, by selected patent sector and S&E article field cited: 2020



USPTO = U.S. Patent and Trademark Office.

Note(s):
See Table SINV-82 for additional detail.

Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2021; Elsevier, Scopus abstract and citation database, accessed May 2021.

Science and Engineering Indicators

University Knowledge Transfer Activities

Licensing and university-based startup activity are two frequently tracked indicators of the technology commercialization component of knowledge transfer by university faculty, staff, and students. The analysis of these activities is based on data from AUTM, a membership organization that supports the technology transfer of academic research.[7] The transfer of knowledge embedded in technology constitutes a special case of knowledge transfer often referred to as technology transfer. This section considers the special case of knowledge transfer in the form of technology transfer from universities to the business sector.

For many technology-based startups, possession of a patent or an exclusive option to license a patent is the first step to attracting external financing. Patented inventions can be licensed directly to an external party, or an exclusive option can be granted for licensing rights at a future date. The startups assessed in this section are companies that are founded using university intellectual property (AUTM 2021). These startup companies reported by universities in AUTM data refer to companies that were formed in the reporting year specifically to develop the technology being licensed.

According to AUTM, in 2019, U.S. universities executed almost 8,000 new licenses or options. Increasingly, these licenses or options are executed by startups and small firms (those with fewer than 500 employees). In 2009, startups accounted for 15% (800) and small businesses 50% (2,597) of new licenses or options (**Table INV-2**). By 2019, university startups accounted for about 1,500 licenses (19%) and small companies licensing university technology accounted for almost 4,700 (59%) (**Table INV-2**). Most university-related startups are located in the home state of the research university; only 26% were in another state in 2019 (**Figure INV-14**). The number of university-related startups launched annually has increased steadily since 2000, and in 2019 AUTM reported a combined 1,029 new university-related startups (**Figure INV-14**).

Table INV-2

University technology licenses or license options executed, by company characteristic: 2009, 2014, and 2019

(Number)

Company characteristic	2009	2014	2019
New licenses or options executed	5,222	6,327	7,974
Startups	800	1,131	1,481
Small companies	2,597	3,064	4,684
Large companies	1,825	2,132	1,809
All licenses, total active	33,523	42,015	49,477

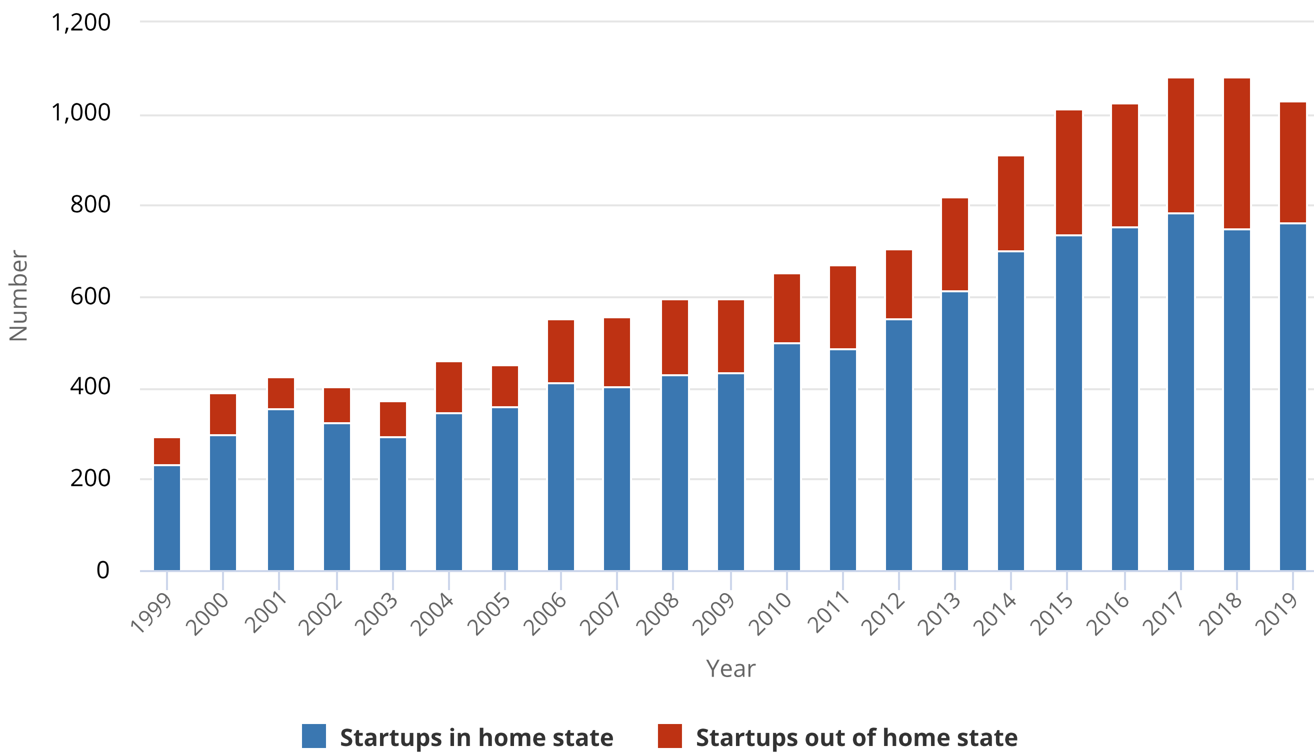
Note(s):
AUTM collects data on invention and patent-related activities of its member universities and hospitals. The number of member universities varies slightly from year to year. There were 248 in 2009, 252 in 2014, and 236 in 2019. Responding institutions may report for any 12-month period ending in the identified year. Startup companies reported by universities in AUTM data refer only to those companies that were formed in the reporting year specifically to develop the technology being licensed. Counts of licenses to startups and small companies are mutually exclusive. Small companies are those with fewer than 500 employees.

Source(s):
AUTM, AUTM Licensing Survey (various years), accessed February 2021.

Science and Engineering Indicators

Figure INV-14

Startup companies based on licensed university technology: 1999–2019



Note(s):
The survey question asks how many startup companies were formed in a given year that were dependent upon the licensing of the institution's technology for initiation. Startup companies reported by universities in AUTM data refer only to those companies that were formed in the reporting year specifically to develop the technology being licensed.

Source(s):
AUTM, STATT Database, Version 4.2, accessed February 2021.

Science and Engineering Indicators

Federal Government Knowledge Transfer Support

Multiple indicators provide insight into how federal R&D contributes to innovation through knowledge transfer. Federal laboratories in multiple agencies or departments facilitate knowledge transfer through the information included in invention disclosures and patents and by way of licenses and collaborative relationships. Collaborative relationships include cooperative R&D agreements (CRADAs), of which the traditional type involves an agreement between a federal agency or laboratory and one or more nonfederal organizations. The nonfederal organization (a business, nonprofit, or other government entity) provides some of its own resources for the research activity. In exchange, the nonfederal organization is granted the option to license resulting technology. Nontraditional CRADAs provide a material transfer or other forms of federal technical assistance that may result in protected information.[8] Additionally, federal laboratories and federal science-funding agencies support startups in many ways, including through the SBIR and STTR programs, the latter of which supports technology transfer from universities.

Nine federal departments or agencies reported R&D obligations of at least $1 billion in 2018, which generated significant new knowledge available for transfer (see *Indicators 2020* report "**Research and Development: U.S. Trends and International Comparisons**"). Some of these departments and agencies report support for startups to the National Institute of Standards and Technology (NIST). For reporting departments and agencies, of the startups that received support from federal laboratories in 2016, the Department of Commerce (DOC) funded the most at 51 (**Table INV-3**).[9] In 2016, the Department of Energy (DOE), with 1,760, and the National Aeronautics and Space Administration (NASA), with 1,554, disclosed the greatest numbers of inventions (**Table INV-3**). DOE had the highest number of patents granted (856 out of 2,341 total) (**Table INV-3**). DOE also had the greatest number of active invention licenses (943) and executed the highest number of new invention licenses (145) (**Table INV-3**). Furthermore, DOE had the highest total active licenses (5,410) (**Table INV-3**). As is the case with university licensing, federal government licensing of its inventions represents the technology transfer special case of knowledge transfer. Patents are used here as indicators of knowledge transfer because the assignment of patent protection allows for subsequent use and commercialization.

Table INV-3

Federal laboratory technology transfer activity indicators, by selected departments and agencies: FY 2016

(Number)

Technology transfer activity	All reporting federal agencies and departments	DOD	DOE	NASA	USDA	DOC	DHS
Total startups supported[a]	na	na	na	19	na	51	0
Invention disclosures and patenting							
Inventions disclosed	5,086	874	1,760	1,554	244	64	17
Patent applications	2,596	941	999	129	109	25	15
Patents issued	2,341	665	856	103	60	16	3
Licensing							
All licenses, total active in the fiscal year	8,950	515	5,410	452	441	57	5
Invention licenses, total active in the fiscal year	4,156	358	943	387	370	57	5
New invention licenses in the fiscal year	572	57	145	97	27	15	1
Collaborative relationships for R&D							
CRADAs, total active in the fiscal year	11,644	3,125	739	12	238	2,940	343
Traditional CRADAs	6,720	2,297	739	12	161	335	272
Other collaborative R&D relationships	18,472	452	0	2,204	11,854	3,273	71

na = not applicable; data not reported at this level.

CRADA = Cooperative R&D Agreement; DHS = Department of Homeland Security; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; NASA = National Aeronautics and Space Administration; USDA = Department of Agriculture.

[a] Startups are companies that have been in existence for 5 years or less.

Note(s):
In addition to the federal departments and agencies listed in the table, the "All reporting federal agencies and departments" totals also include the Department of Health and Human Services, the Department of the Interior, the Department of Transportation, the Department of Veterans Affairs, and the Environmental Protection Agency. Invention licenses refer to inventions that are patented or could be patented. CRADAs refer to all agreements executed under CRADA authority (15 U.S.C. 3710a). Traditional CRADAs are collaborative R&D partnerships between a federal laboratory and one or more nonfederal organizations. In addition to CRADAs, federal agencies have varying authorities for other kinds of collaborative R&D relationships, such as Space Act Agreements (NASA) or other transaction authorities. Agency support for startups is defined as critical technical support (NIST 2019).

Source(s):
National Institute of Standards and Technology (NIST), U.S. Department of Commerce, *Federal Laboratory Technology Transfer, Fiscal Year 2016: Summary Report to the President and the Congress* (2019), accessed 10 January 2021.

Science and Engineering Indicators

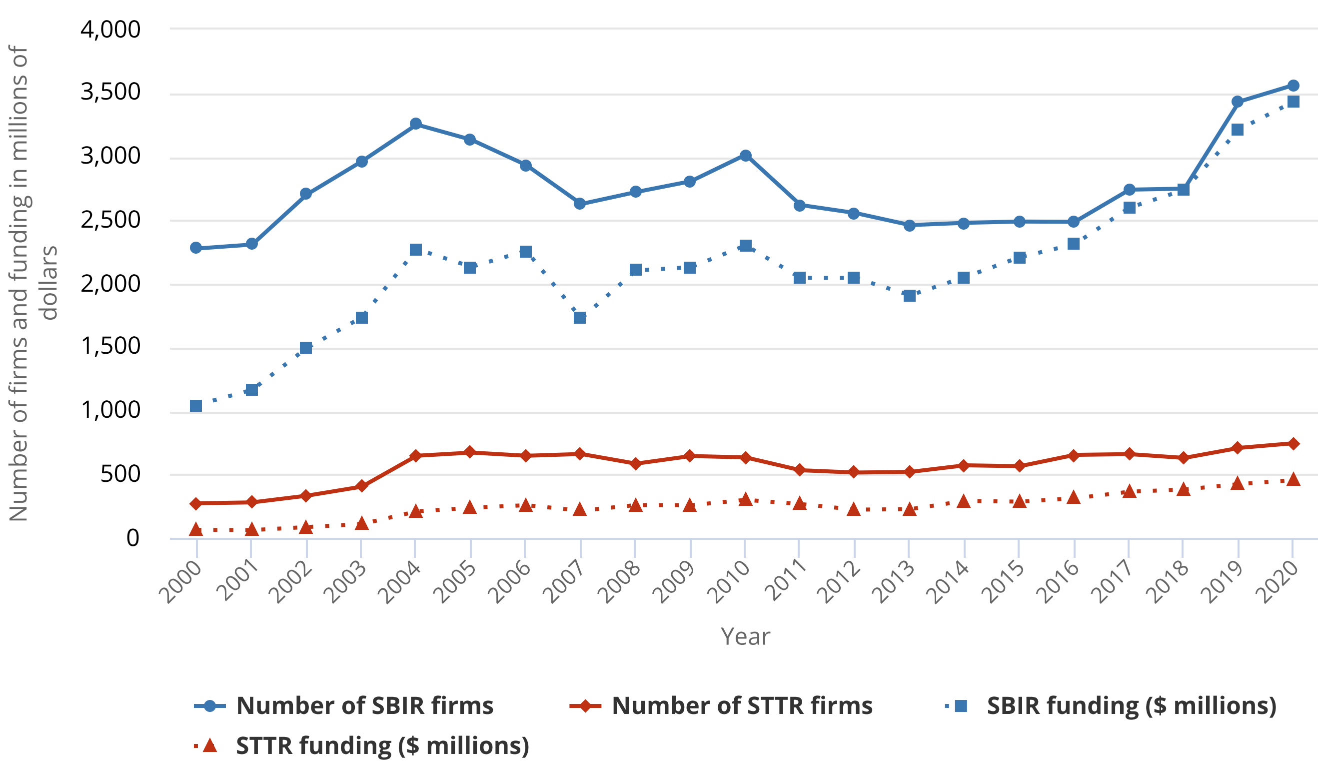
Collaborative relationships were unevenly distributed among the six federal departments. Of the 30,116 active collaborations across all federal laboratories, the U.S. Department of Agriculture was involved in more than a third (12,092), and most of these (11,854) were not CRADAs (**Table INV-3**). With 27% and 25%, respectively, the Department of Defense and DOC had the greatest proportions of the 11,644 active CRADAs in 2016 (**Table INV-3**). These data suggest that the CRADA mechanism is suitable for establishing collaborations by some agencies, but other mechanisms, such as licensing, appear better able to meet the needs of other agencies.

Focused cross-agency federal initiatives strive to strengthen the development and flow of early-stage technologies into the commercial marketplace. The most substantial federal initiatives focused on small companies are two complementary programs, SBIR and STTR. Both are administered by the U.S. Small Business Administration with the goal of fostering innovation among domestic small businesses engaged in R&D activities to meet federal R&D needs. These two programs provide competitively awarded funding to small businesses (fewer than 500 employees) with the goal of stimulating technological innovation to address federal R&D needs. The programs are run through individual federal agencies with extramural research budgets of $100 million or greater. Many of the program recipients are startups, especially those receiving funds as part of the STTR program.

Established in 1992, the STTR program focuses on partnerships between small businesses and universities or other nonprofit research institutions. Accordingly, it plays a large role in knowledge transfer, and program award data provide a useful indicator of the same. The number of firms supported by the program rose from 272 in 2000 to 745 in 2020 (**Figure INV-15**). Program funding grew from $63 million to $455 million over the same period.

Figure INV-15

SBIR and STTR programs, by number of firms and total funding: FYs 2000–20



SBIR = Small Business Innovation Research; STTR = Small Business Technology Transfer.

Note(s):
Funding data are awarded amount through FY 2014; obligated amount in FY 2015 and later.

Source(s):
Small Business Administration, SBIR/STTR official website, accessed August 2021.

Science and Engineering Indicators

SBIR participant companies often rely on third parties to help perform program-funded research, the results of which are transferred to participants. SBIR program data therefore also provide an indication of knowledge transfer, albeit a less direct one. The SBIR program conferred awards to 3,564 firms in 2020, up from 2,277 in 2000. The 2020 awards accounted for almost $3.5 billion in funding (**Figure INV-15**).

At the state level, SBIR and STTR funding as a ratio to state gross domestic product provides a direct measure of federal support for small businesses. These data are available in the National Science Board's **State Indicators Data Tool**. From 2016 to 2018, the SBIR ratio is highest in two New England states, Massachusetts and New Hampshire, followed by New Mexico and Colorado (NSB 2021b).

Increasingly, another form of shared knowledge is original computer software created for government activities throughout the U.S. federal government. Much of this software has the potential for reuse, both inside and outside of government. The U.S. federal government supports the sharing of software developed by and for the federal government through its Federal Source Code Policy, which provides a framework for government code to be released and reused through OSS licensing. This policy allows software created for narrow federal purposes to be reused elsewhere within the federal government, multiplying its value to the government, and outside of the federal government, further extending its impact.

One indication of the increasing activity of federal departments and agencies is the sharing of computer software repositories with an Open Source Initiative (OSI)–approved license on the GitHub platform. Repositories contain all of the files and folders associated with a specific OSS project and can be owned by individual entities or shared across multiple entities. While this measure based on GitHub is not comprehensive (federal agencies may share through separate platforms), it shows that from 2010 to 2019, the 10 most active federal department and agency participants in OSS sharing contributed to over 15,000 distinct OSS repositories (**Table INV-4**). Representative government-contributed OSS projects include DOE's Raven, code for performing risk analysis of nuclear reactor systems, and DOE's Qball, code for performing molecular dynamics to compute the electronic structure of matter. Not surprisingly, because DOE and NASA were early adopters of OSS, these two agencies have the largest number of repositories among federal agencies. In 2009, only DOC, DOE, and NASA used open-source platforms to share software with other users; by 2019, 21 agencies did so (Table SINV-83).

Table INV-4

Cumulative contribution of selected entities to open-source software on GitHub: 2010–19

(Number)

Institution	Count of repositories contributed to by institutional members
Federal total	15,716
Department of Energy	11,156
National Aeronautics and Space Administration	1,102
Department of Health and Human Services	863
Department of Commerce	819
Department of the Interior	537
Department of Defense	321
General Services Administration	319
Smithsonian Institution	107
Department of Agriculture	104
Department of Veterans Affairs	76
All other federal departments and agencies	312

Table INV-4

Cumulative contribution of selected entities to open-source software on GitHub: 2010–19

(Number)

Institution	Count of repositories contributed to by institutional members
Selected business and university repositories	57,284
Microsoft	25,365
RedHat	24,767
University of California, Berkeley	7,152

Note(s):
Included repositories are those public on GitHub with machine detectable Open Source Initiative-approved licenses that received contributions from affiliates from each organization; software shared through other licenses are excluded. Public higher education institutions and selected private entities are included as benchmarks. The Department of Energy encompasses 17 national laboratories, 16 of which were included in the data. The exception is the Department of Energy's SLAC National Accelerator Laboratory, formerly known as Stanford Linear Accelerator. Due to data constraints, these repositories are attributed to the operator (Stanford), rather than to the Department of Energy. Overall, in terms of number of repositories, Microsoft and RedHat are the two largest contributors from the private sector and UC Berkeley from higher education institutions.

Source(s):
Robbins C, Korkmaz G, Guci L, Santiago Calderón J, Kramer B. 2021. *A First Look at Open-Source Software Investment in the United States and in Other Countries, 2009–2019*.

Science and Engineering Indicators

SIDEBAR

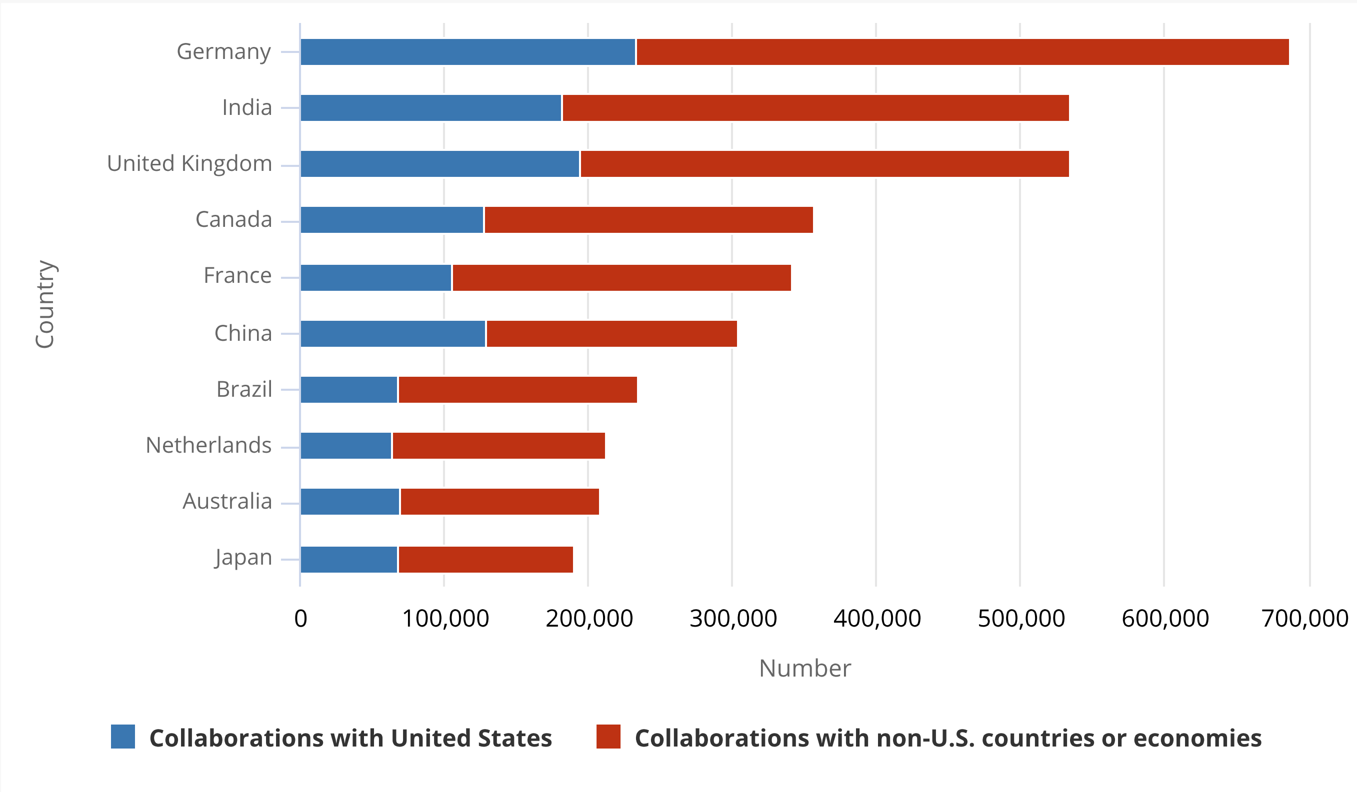
Sidebar: U.S.-International Collaborations in Open-Source Software

Developers throughout the world collaborate widely through the creation of open-source software (OSS). GitHub, the world's largest remote source code–hosting platform, provides tools to collect user attribute and activity data that can be analyzed to assess OSS collaborations across countries. Collaboration is defined in terms of pairs of individuals that contribute code to a common repository. Similar to the way in which research publication records show patterns of collaboration in the *Indicators* report "[2022] Publications Output: U.S. Trends and International Comparisons," OSS collaboration networks show international relationships in knowledge creation and transfer.

The dataset used for analysis contains each GitHub repository with an open-source license as well as information on the location of each repository's contributors for 2018. For OSS developers in the United States with projects on GitHub, cooperation was most frequent with collaborators from Germany, followed by the United Kingdom, and India (**Figure INV-A**). This collaboration pattern differs from that of peer-reviewed publications in which authors from the United States are most often collaborating with Chinese coauthors (see *Indicators* report "[2022] Publications Output: U.S. Trends and International Comparisons").

Figure INV-A

International collaborations with the United States and with non-U.S. countries in development of open-source software, by 10 largest contributing countries: 2018



Note(s):
Collaborations are counted using whole counts by which each collaboration partner receives one count for each open-source software collaboration identified in GitHub.

Source(s):
Robbins C, Korkmaz G, Guci L, Santiago Calderón J, Kramer B. 2021. *A First Look at Open-Source Software Investment in the United States and in Other Countries, 2009–2019*.

Science and Engineering Indicators

U.S. Startup Trends

A significant amount of knowledge transfer to startup companies takes place via startup licensing of university and government technology and from startup participation in government programs like STTR. However, many startups that rely on outside knowledge as the basis for their new products and processes neither license that outside knowledge nor participate in government programs. Data from university technology transfer offices, for example, indicate that just over 1,000 university-related startups were formed in 2019 (**Figure INV-14**). Thus, the data described in preceding sections do not account for all knowledge transfer to startups.

According to the U.S. Census Bureau, over 400,000 firms in the United States were less than one year old in 2018. Many factors influence startup activity, not only transfer of science and technology knowledge. That said, data on trends for total new firm formation provide a top-down and indirect view of knowledge transfer to startups over time that complements license and program participation data. An increase or decrease in new firm formation could be expected to correlate with overall knowledge transfer to new firms. In other words, if many more or many fewer new firms are formed, it is likely that a correspondingly larger or smaller number of new firms are making use of external knowledge. From 1990 to 2018, the number of new firms (those less than a year old) fell from 494,000 to 431,000 (**Figure INV-16**). While it may be the case that the share of young firms relying on external science and technology knowledge has grown during this period, this long-term decline in new firm formation suggests a decline in the flow of knowledge into this sector of the economy or other factors holding back firm formation.

Figure INV-16

New firms and employment from new firms: 1990–2018

Note(s):
New firms are firms less than one year old. Number of jobs created is from opening establishments during the last 12 months.

Source(s):
U.S. Census Bureau, Business Dynamics Statistics, accessed March 2021.

Science and Engineering Indicators

SIDEBAR

Sidebar: Citizen Science in Federal Agencies and Departments

Learning by doing is a way for innovation to occur through practical activities. By allowing individuals to participate in organized science activity, knowledge is transferred to the lay public to use. Citizen science is a form of open collaboration in which individuals or organizations participate as volunteers in scientific progress. Approximately 10% of U.S. adults say that they have taken part in citizen science in the past year, and just over a quarter (26%) say that they have participated in citizen science within their lifetime (Thigpen and Funk 2020). The forthcoming *Indicators* report “[2022] Science and Technology: Public Perceptions, Awareness, and Information Sources” covers this topic from the perspective of participating individuals and public perceptions of science. Here, the focus is on how federal science agencies support citizen science. Data collected from the U.S. federal government website, citizenscience.gov, provide the number of citizen science projects per agency and the tasks in which citizen scientists engage.

In 2020, there were 268 citizen science projects sponsored by U.S. federal agencies and departments and reported on citizenscience.gov (**Table INV-A**). With 174 projects, the National Park Service leads federal agencies and departments in sponsoring citizen science projects, followed by the National Science Foundation (NSF) at 77 and National Oceanic and Atmospheric Administration at 60 (**Table INV-A**).

Table INV-A

Federally sponsored citizen science projects on citizenscience.gov, by federal department or agency: 2020

(Number)

Sponsor	Number
National Park Service	174
National Science Foundation	77
National Oceanic and Atmospheric Administration	60
U.S. Environmental Protection Agency	47
U.S. Geological Survey	44
U.S. Department of Agriculture	37
National Aeronautics and Space Administration	28
U.S. Forest Service	21
U.S. Fish and Wildlife Service	16
Smithsonian Institution	14
National Institutes of Health	12
Department of Energy	8
U.S. Department of the Interior	8
Centers for Disease Control and Prevention	7
Bureau of Land Management	4
All other U.S. federal projects	22

Source(s):
citizenscience.gov, tabulated by SRI International, February 2021.

Science and Engineering Indicators

Beyond those identified as sponsored by the federal government, in 2020, more than 4,000 such projects were listed on citizen science websites and databases (SRI International 2020). There are now citizen science associations in the United States, the European Union, and Australia (Heigl et al. 2019). Compared with patenting activity (as described in the **Invention Indicators: Protecting Useful Ideas** section of this report) and the completion of advanced degrees in science (NSB 2020), participation by men and women is more balanced. According to a Pew Research Center survey, roughly half of citizen science participants in the United States are female (Thigpen and Funk 2020). See the forthcoming *Indicators* report “[2022] Science and Technology: Public Perceptions, Awareness, and Information Sources” for more discussion about Americans’ participation in citizen science activities and their perception of it.

Innovation Indicators: Introducing New Products and Processes

The previous sections of this report examined indicators of invention output and knowledge transfer activities. As described earlier, invention represents a subset of R&D output that includes new and useful processes, machines, manufactures, or compositions of matter, or any new and useful improvements thereof. Knowledge transfer, the second theme of this report, encompasses the activities by which this newly created knowledge is shared with those who can apply it, further develop it, and transform it into new outputs, including innovation outputs.

For measurement purposes, innovation has an internationally agreed upon definition. The Organisation for Economic Co-operation and Development (OECD) defines an innovation as a new or improved product or process that differs significantly from previous products or processes and that the innovator has made available to potential users or brought into use (OECD Eurostat 2018). The implementation of these ideas as products or processes with real-world applications is what separates inventions from innovations. There is broad consensus among countries that policies at the national level should encourage and support innovation because innovation supports economic growth and advances knowledge (OECD 2010). Accordingly, many countries use policies that promote innovation to foster the creation of new products and processes.

This section presents a range of indicators of innovation output, starting with data on the introduction of new or significantly improved products and processes by U.S. businesses, from a joint NCSES and U.S. Census Bureau survey. Examined next are data on the registration of new trademarks from the USPTO and from other national intellectual property (IP) offices collected via WIPO. As described by von Graevenitz, Graham, and Myers (2019), trademark registrations "capture the moment at which products or services are introduced into the market, turning inventions into innovations." Thus, trademarks represent another direct measure of innovative output by firms. Compared with patenting, trademarking is easier and less costly, and it does not have the same requirements regarding novelty (Millot 2009); consequently, small and new businesses apply for trademarks more frequently than they apply for patents (Greenhalgh et al. 2011; Seip, Castaldi, and Flikkema 2019). Therefore, trademarks can reveal service, marketing, and organizational innovation that would not otherwise be captured because the source of innovation is not always tied to technological advances (Castaldi, Block, and Flikkema 2020).

In addition to these direct measures of innovation output from the private sector, several indirect innovation indicators connected to venture investment and new firm formation are presented. Access to financing is an essential component of the translation of new knowledge into innovations. Entrepreneurs rely on a variety of sources of financing, including their own funds, friends and family, bank loans, government support, angel investment, and venture capital (OECD 2014). Venture capital is a particularly important indicator of innovation because venture investors tend to invest in companies whose products they believe have a significant likelihood of achieving market success. Venture capital firms that become publicly traded are more likely to have recorded R&D expenditures compared to publicly traded firms that were not originally venture-backed (Lerner and Nanda 2020). In this regard, data on U.S. and global venture capital investment trends, provided by PitchBook, can be viewed as leading indicators of the innovative output expected from startups as they use those funds to create innovations. Of particular focus in this chapter is the expanding role of China in the global venture investment landscape.

Annual state-level data on venture capital disbursed relative to state gross domestic product (GDP), available in the National Science Board's **State Indicators Data Tool**. At the state level, the highest venture capital/GDP ratios are in California and Massachusetts (NSB 2021c). Data from the U.S. Census Bureau's Business Dynamics Statistics on firm formation are presented below as a complement to the venture capital data. These additional data provide a view of the total number of small firms in the United States and their associated employment levels. Although they indicate innovative output only indirectly, statistics on new firm formation and employment correlate with overall levels of innovation.

The central role of the business sector in innovation activity has shaped the available data, and most indicators of innovation address the private sector. Notwithstanding the availability of data, however, a diverse set of actors that span the economic sectors of the economy contribute to the creation of innovative output, including universities, government agencies, and citizen scientists. The impact of government and private citizens on innovation is briefly discussed toward the end of this section. As robust indicators are not currently available for evaluation of their innovation output, patent data from the **Invention Indicators: Protecting Useful Ideas** section that bear on the inventive outputs of these two groups are highlighted.

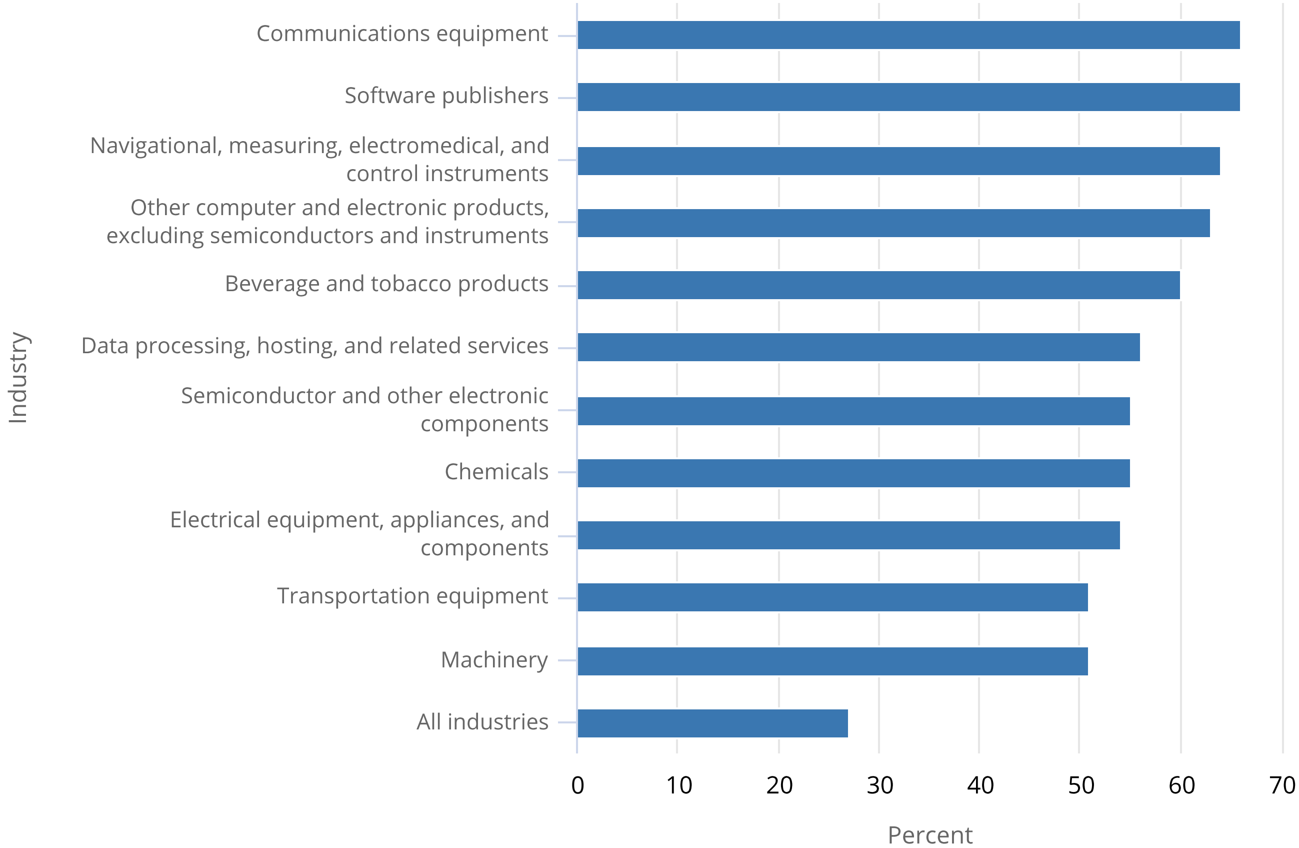
The section concludes with a sidebar on vaccine development during the COVID-19 pandemic. The sidebar discusses the rapid innovation achievable when a deep basis of scientific knowledge has been created through decades of federally and privately funded research and when knowledge transfer is accelerated through the intensely collaborative activities of academia, government, the nonprofit sector, and private companies.

Business Innovation

High rates of innovation activity in the business sector indicate a dynamic economy, whether at the local, regional, or national level (Hall and Jaffe 2018). A key indicator of business innovation activity is the proportion of companies within an industry that introduces new or significantly improved products and processes. In the United States, over 1 million businesses introduced a new or significantly improved product or process from 2015 to 2017, representing 27% (approximately one in four) of businesses, according to the ABS (**Figure INV-17**).[10] Compared with the one in six businesses reported in the *Indicators 2020* report "**Invention, Knowledge Transfer, and Innovation**," this increase in the reported ratio is affected by the evolution of the U.S. business innovation survey to cover innovation more comprehensively (NCSES 2021).

Figure INV-17

Share of U.S. companies reporting product or process innovation, by selected industry: 2015–17



Note(s):
Classification is by 2017 North American Industry Classification System codes and based on the dominant establishment payroll. Statistics are representative of companies located in the United States. Industries shown in the table are those in which more than half of the firms within the industry reported an innovation in the 3-year period from 2015 to 2017. For this survey, an innovation must have characteristics or intended uses that are new or that provide a significant improvement over what was previously used or sold by the business. Product innovations may be goods or services. Process innovations may be methods of manufacturing; logistics, delivery, or distribution methods; or supporting activities, such as maintenance or operations systems.

Source(s):
National Center for Science and Engineering Statistics and U.S. Census Bureau, Annual Business Survey, 2017.

Science and Engineering Indicators

More than half of the businesses in 11 industries reported innovation activity, above the national average for all industries of 27% (**Figure INV-17**). Many of these companies are in manufacturing industries; 45% (99,847) of manufacturing companies surveyed reported the release of new or significantly improved products or processes. Nine of the eleven industries reporting innovation rates above 50% were manufacturing industries, confirming the overall high prevalence of innovation in that sector (**Figure INV-17**).

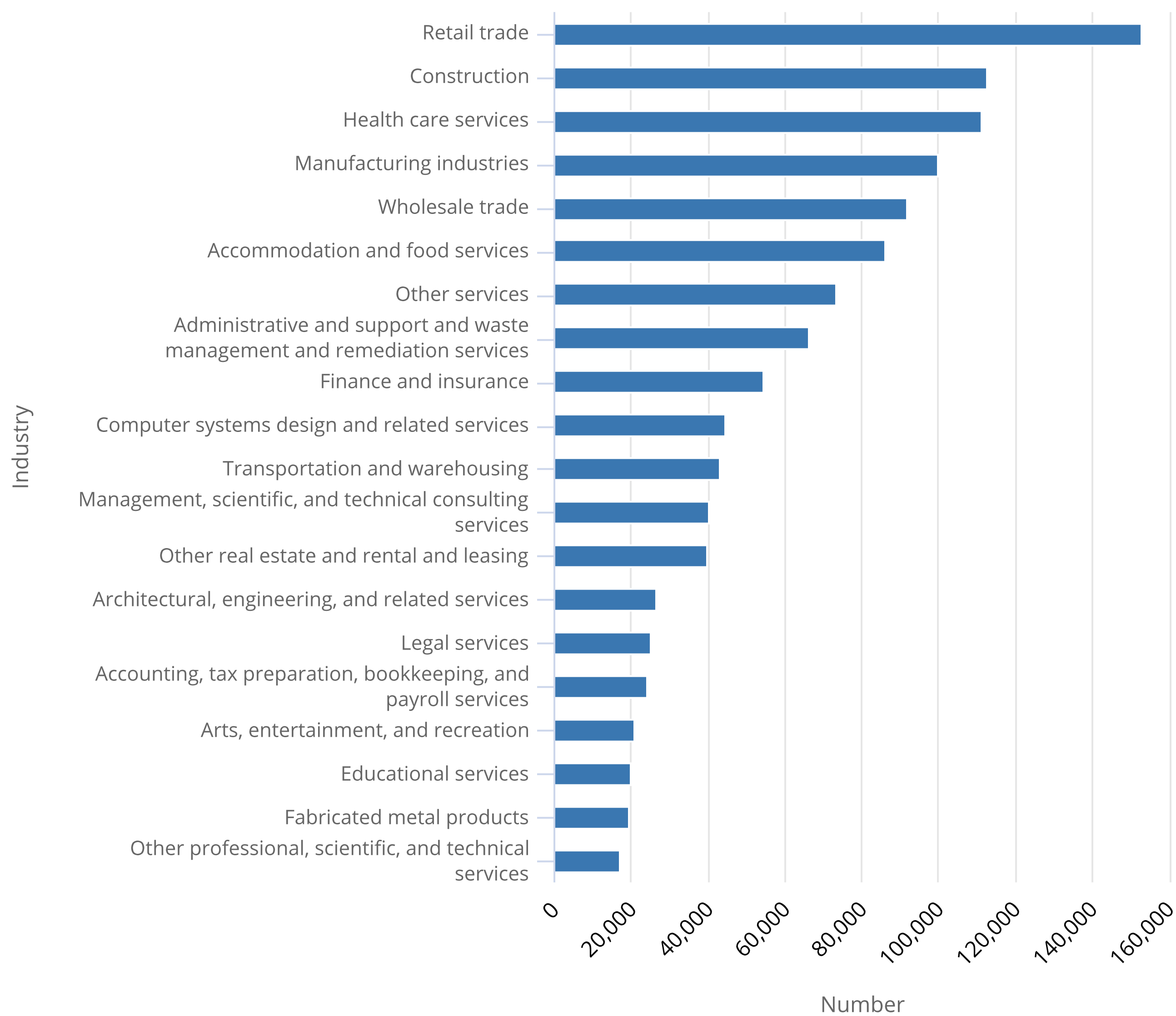
The manufacturing industry with the highest proportion of innovative companies was communications equipment (66%) (**Figure INV-17**). Chemical companies also had high innovation rates (55%) due to the inclusion of the pharmaceutical industry, which is R&D- and patent-intensive (**Figure INV-17**).

Two information industries—data processing and related services (56%) and software publishers (66%)—were among the 11 industries reporting high rates of companies with new products or processes (**Figure INV-17**). Overall, innovation rates in the United States are relatively high for parts of the manufacturing and information industries.

Looking at absolute numbers, the retail trade industry reported the most companies (152,920) introducing a new or significantly improved product or process from 2015 to 2017 in the United States (**Figure INV-18**). The only other industries reporting more than 100,000 companies introducing product or process innovations during this period were construction (112,877) and health care services (111,310) (**Figure INV-18**). However, the ranking of retail trade and health care services as two of the top industries is partly explained by those industries accounting for the largest share of firms; nearly half a million of all the surveyed companies were in each of those two industries (545,440 and 447,069, respectively).

Figure INV-18

U.S. companies introducing product or process innovation, by selected industry: 2015–17



Note(s):
For this survey, an innovation must have characteristics or intended uses that are new or that provide a significant improvement over what was previously used or sold by the business. Product innovations may be goods or services. Process innovations may be methods of manufacturing; logistics, delivery, or distribution methods; or supporting activities, such as maintenance or operations systems. Classification is by 2017 North American Industry Classification System codes and based on the dominant establishment payroll. Statistics are representative of companies located in the United States.

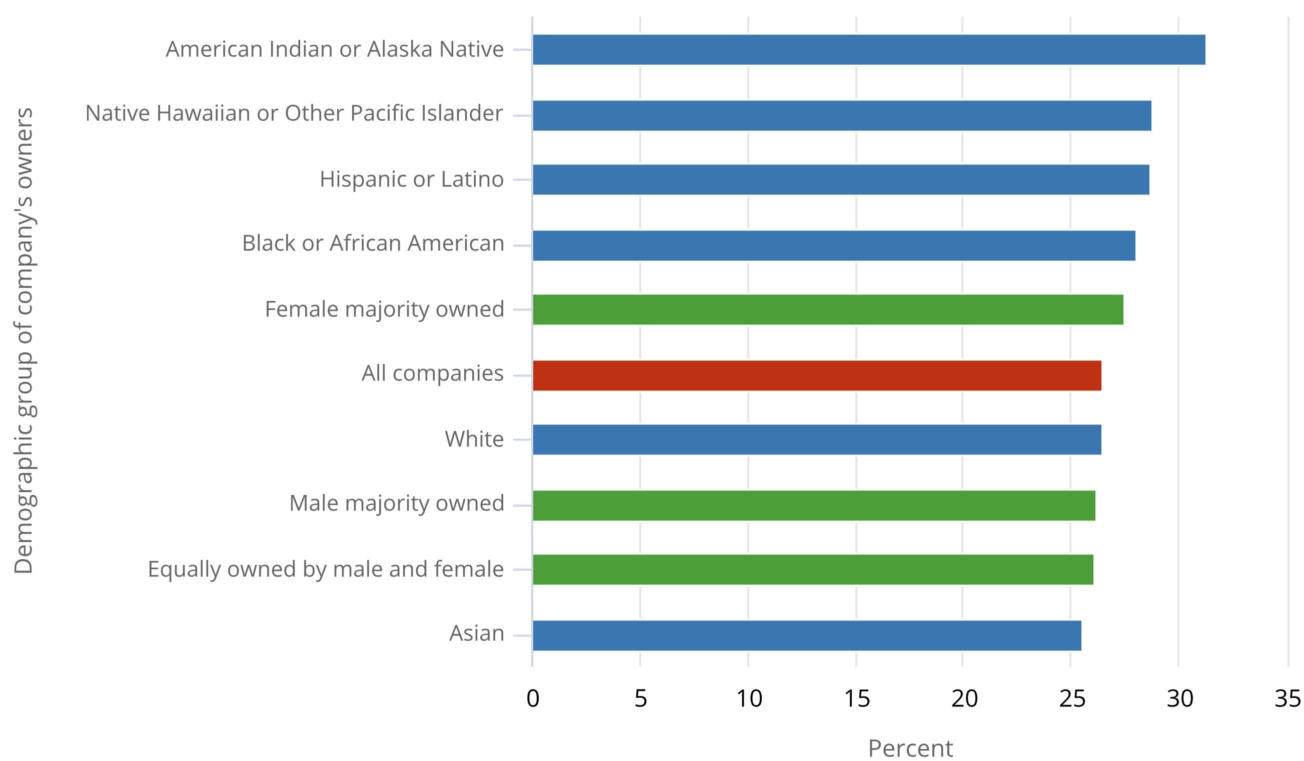
Source(s):
National Center for Science and Engineering Statistics and U.S. Census Bureau, Annual Business Survey, 2017.

Science and Engineering Indicators

The ABS includes new demographic data on innovation rates of firms that are majority-female-owned and majority-male-owned. From 2015 to 2017, majority-female-owned firms reported slightly higher innovation rates (27.5%), compared with majority-male-owned firms (26.2%) (**Figure INV-19**). That said, these majority-female-owned firms represent only 20% of all firms (NCSES 2018). Newly available survey data also show that firm owners who identify as Black (or African American) or Hispanic (or Latino) report slightly higher process and product innovation rates. From 2015 to 2017, 28.0% of firms whose owners reported their race as Black or African American introduced a product or process innovation compared to 26.5% of firms who reported their race as White (**Figure INV-19**). For business owners who reported their ethnicity as Hispanic or Latino, 28.7% reported an innovation compared to 26.3% for those who reported their ethnicity as non-Hispanic (**Figure INV-19**). However, Black or African American owners account for only 2% of all firms, and Hispanic or Latino firms account for only 5% of all firms. Overall, this suggests that women and underrepresented minorities, while underrepresented as business owners, are making above average contributions to innovation in business.

Figure INV-19

Share of U.S. companies introducing product or process innovations, by owners' sex, race, and ethnicity: 2015–17



Note(s):
For this survey, an innovation must have characteristics or intended uses that are new or that provide a significant improvement over what was previously used or sold by the business. Product innovations may be goods or services. Process innovations may be methods of manufacturing; logistics, delivery, or distribution methods; or supporting activities, such as maintenance or operations systems. Classification is by 2017 North American Industry Classification System codes and based on the dominant establishment payroll. Statistics are representative of companies located in the United States.

Source(s):
National Center for Science and Engineering Statistics and U.S. Census Bureau, Annual Business Survey, 2017.

Science and Engineering Indicators

Trademarks: U.S. Trends

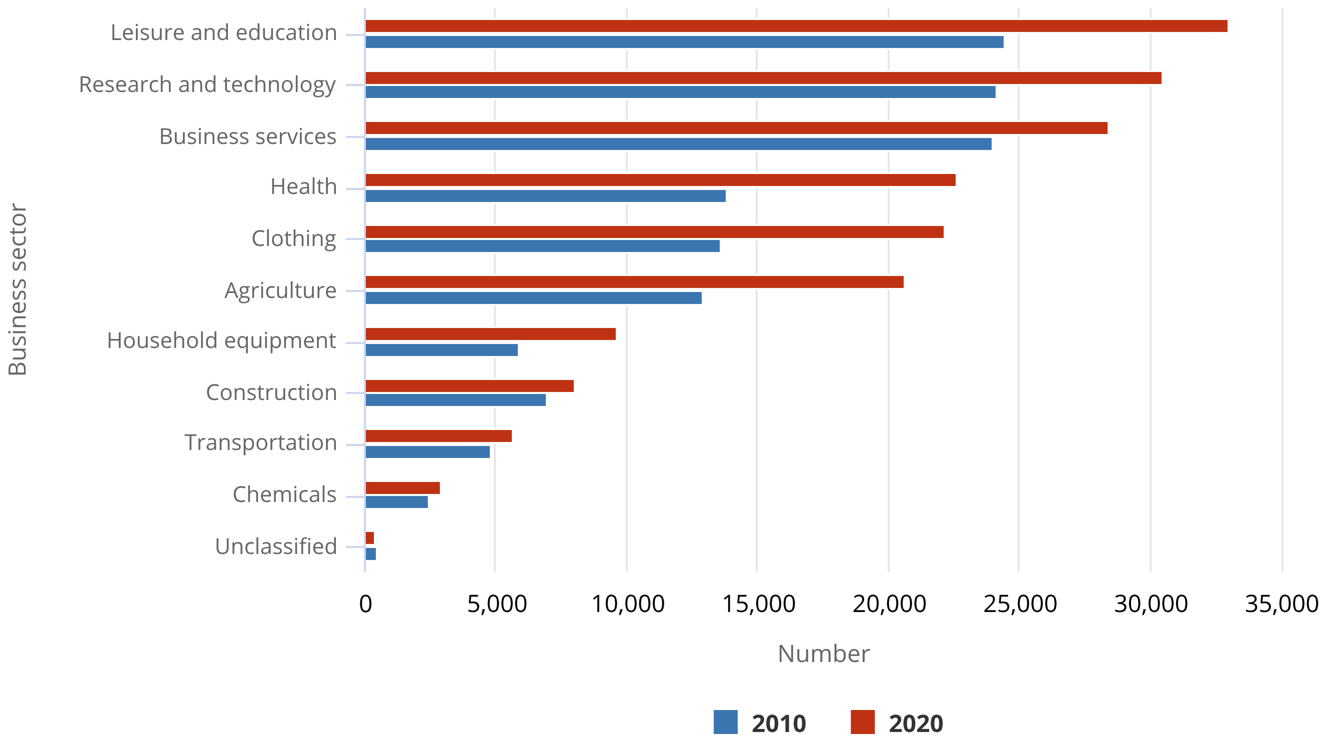
Trademarks provide legal registration and protection to commercially used symbols, images, and names. The application and registration of a trademark is a way to announce to the market that the firm has introduced a new product, thus making a useful indicator of innovative output. Trademarks also signify when newly registered products are different from others in the market (Castaldi, Block, and Flikkema 2020). For companies in the United States that either perform or fund R&D, trademarks are considered as important as utility patents as an intellectual property protection strategy, as shown in the **Invention Indicators: Protecting Useful Ideas** section of this report (**Figure INV-5**).

Trademark registration is a significant and lower-cost way, compared to patents, for startups to signal the potential value of their innovative assets. Firms often wait until a successful product has been developed before registering a trademark (Castaldi, Block, and Flikkema 2020). Trademark registration is typically associated with later stages of the innovative process than are patents, signaling those new products and processes are ready for introduction to the market. Trademark ownership increases the probability of venture capital investment (Zhou et al. 2016), suggesting trademarking is a signal to venture capital firms of the commercial readiness of startup technology.

Along with other indicators of the disruption of economic activity in 2020, the number of USPTO trademarks registered dropped 9% from 2019 to 283,479 in 2020, breaking a decade of consistent growth (Table SINV-84). Products receiving trademark protection provide an indication of industries with high innovation activity. Across product types, knowledge-intensive products and services account for high numbers of trademarks. For U.S.-registered USPTO trademarks in 2020, the top product categories were leisure and education, research and technology, and business services (**Figure INV-20**).

Figure INV-20

Number of U.S.-registered USPTO trademarks, by business sector: 2010 and 2020



USPTO = U.S. Patent and Trademark Office.

Note(s):
Trademarks are allocated according to holder information and are fractionally allocated to regions, countries, or economies based on the proportion of residences of all named holders. Trademarks are classified under the 11th edition of the Nice classification of goods and services, which classifies trademarks under 34 categories of goods and 11 categories of services. Fractional counts of trademarks were assigned to each category to assign the proper weight of a trademark to the corresponding category under the classification. See Table SINV-87 through Table SINV-97 for other years and countries. See Table SINV-85 for detail on the 10 aggregate business sectors.

Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; USPTO data hosted by Reed Tech (LexisNexis), accessed June 2021.

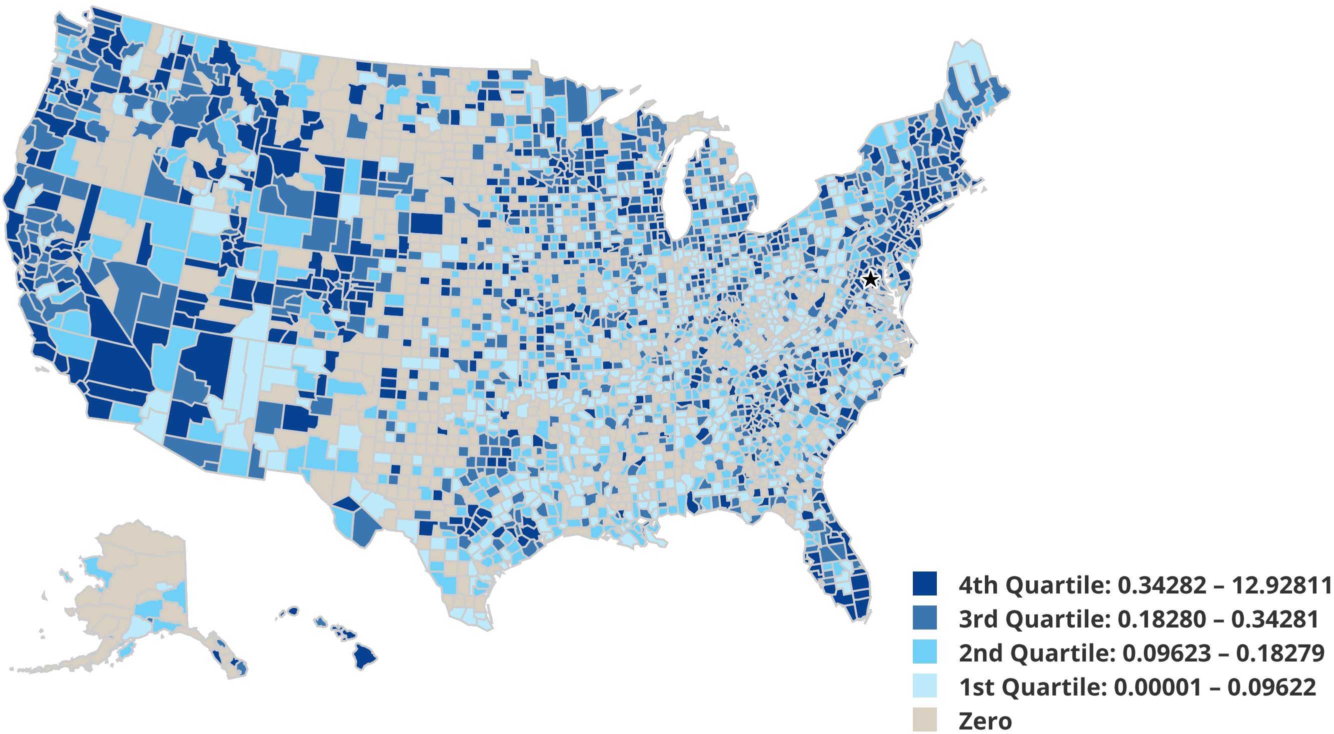
Science and Engineering Indicators

The Geography of U.S. Trademarking

Geographic clustering of knowledge creation and innovation are well established features of innovation systems. As an indicator of the introduction of new products, innovation may well have more potential to affect economic growth at the regional level compared with inventions that may never be implemented (Carlino and Kerr 2015). County-level trademarks issued by the USPTO are shown per 1,000 residents, revealing that trademark activity is unevenly spread across the United States with more intensive activity along the coasts, the Rocky Mountain region, parts of Texas, and the Great Lakes region (**Figure INV-21**).[11] In 2020, 25.7% of all counties had zero trademarks issued, making trademark activity more geographically disbursed across the interior of the United States compared with the regional patenting described in the **Invention Indicators: Protecting Useful Ideas** section of this report, in which 41.6% of counties had zero patents. The top three counties in 2020 for trademark intensity are Sheridan County in Wyoming, followed by Fairfax City in Virginia, and New York County in New York (**Figure INV-21**).

Figure INV-21

Number of registered USPTO trademarks per 1,000 residents, by U.S. county: 2020



USPTO = U.S. Patent and Trademark Office.

Note(s):
USPTO Trademarks are allocated according to holder information. U.S. addresses were geocoded to 3,143 U.S. counties according to U.S. states, U.S. cities, and zip codes appearing in these addresses. Trademarks are classified under the 11th edition of the Nice classification of goods and services, which classifies trademarks under 34 categories of goods and 11 categories of services. Fractional counts of trademarks were assigned to each category to assign the proper weight of a trademark to the corresponding category under the classification. These counts are then grouped under 10 industry sectors following a mapping defined by Edital. See File Supplemental Workbook INV-3 for additional detail.

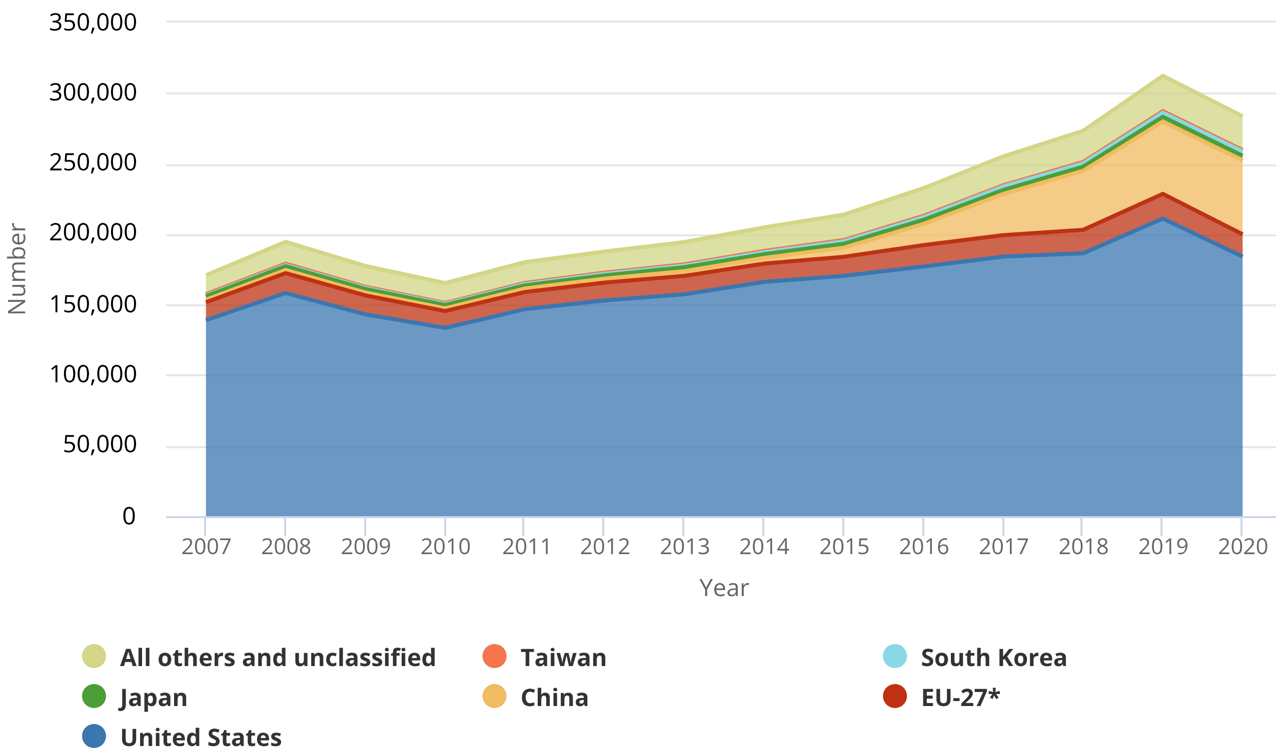
Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; USPTO data hosted by Reed Tech (LexisNexis), accessed June 2021; Population data from the U.S. Census Bureau accessed June 2021 at https://www.census.gov/newsroom/press-releases/2021/2020-vintage-population-estimates.html.

Science and Engineering Indicators

At the international level, the internationalization of commerce has coincided with an increasing share of USPTO trademarks registered to foreign assignees. Since 2008, the number of foreign-registered USPTO trademarks has grown 174%, compared with 16% growth in the number of USPTO trademarks registered to U.S. assignees (**Figure INV-22**). While those from the EU maintained a steady presence, the number of trademarks from China grew more than 20-fold during this period (**Figure INV-22**).

Figure INV-22

Number of registered USPTO trademarks, by selected region, country, or economy: 2007–20



USPTO = U.S. Patent and Trademark Office; EU = European Union.

*Beginning in 2020, the United Kingdom was no longer a member of the EU.

Note(s):
Trademarks are allocated according to holder information. Trademarks are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named holders. China includes Hong Kong. Trademarks are classified under the 11th edition of the Nice classification of goods and services, which classifies trademarks under 34 categories of goods and 11 categories of services. Fractional counts of trademarks were assigned to each category to assign the proper weight of a trademark to the corresponding category under the classification. See Table SINV-84 for additional countries.

Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; USPTO data hosted by Reed Tech (LexisNexis), accessed June 2021.

Science and Engineering Indicators

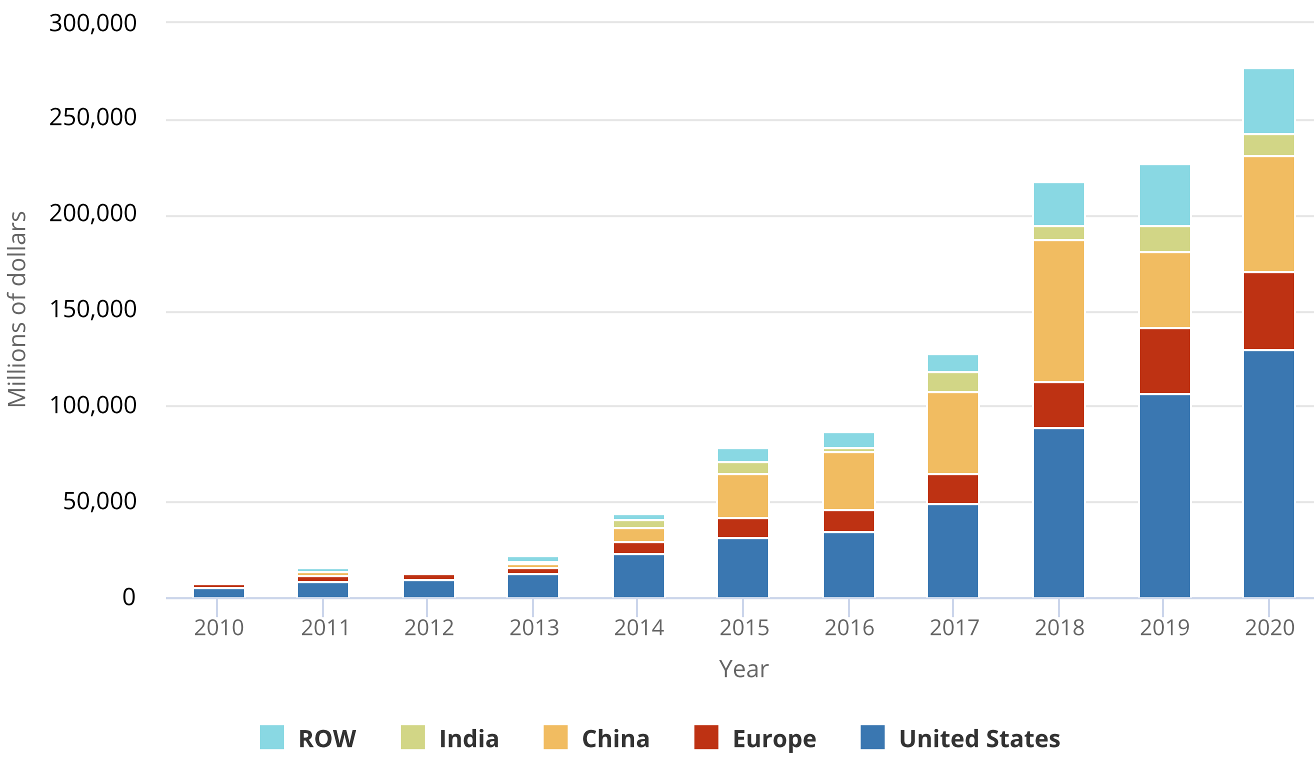
The growth in USPTO trademarks and patents from China is driven by both market and nonmarket factors (USPTO 2021a). Market factors include economic growth and increased exposure to international trade. According to a recent USPTO report, the nonmarket factors behind the increase in trademark activity in China includes government subsidies for foreign trademark applications that exceed the cost of filing and government mandates requiring an increase in trademark filing (USPTO 2021a).

Venture Capital from a Global Perspective

Venture capital provides funding for startups and early-stage firms. Because early-stage firms have a high risk of failure, venture investors pursue a portfolio approach to their investments. Vehicles for this early-stage venture capital include accelerators, crowdfunding, and angel investors, while mutual funds, hedge funds, corporations, and sovereign wealth funds focus more heavily on later stage firms (Lerner and Nanda 2020). Despite the potential headwinds of the global pandemic, global venture capital investment measured in current dollars rose 22% from 2019 to 2020, to a total of $277 billion in 2020 according to data from PitchBook. The United States remains the leading country recipient of venture capital funds, with U.S.-headquartered firms receiving 47% ($129 billion) of total global venture capital funds (**Figure INV-23**). Firms headquartered in China received the second largest amount, with $60 billion in venture capital funds or 22% of the global share (**Figure INV-23**). As a region, firms headquartered in Europe received 15% ($41 billion) of total venture capital in 2020; firms headquartered in India received 4% ($12 billion) of the global total.

Figure INV-23

Global venture capital investment, by selected country, region, or economy: 2010–20



ROW = rest of the world.

Note(s):
China includes Hong Kong. Country, region, and economy is attributed to location of the headquarters of the investing company. See Table SINV-98 for additional regions or countries.

Source(s):
Venture capital and private equity database, PitchBook, accessed September 2021.

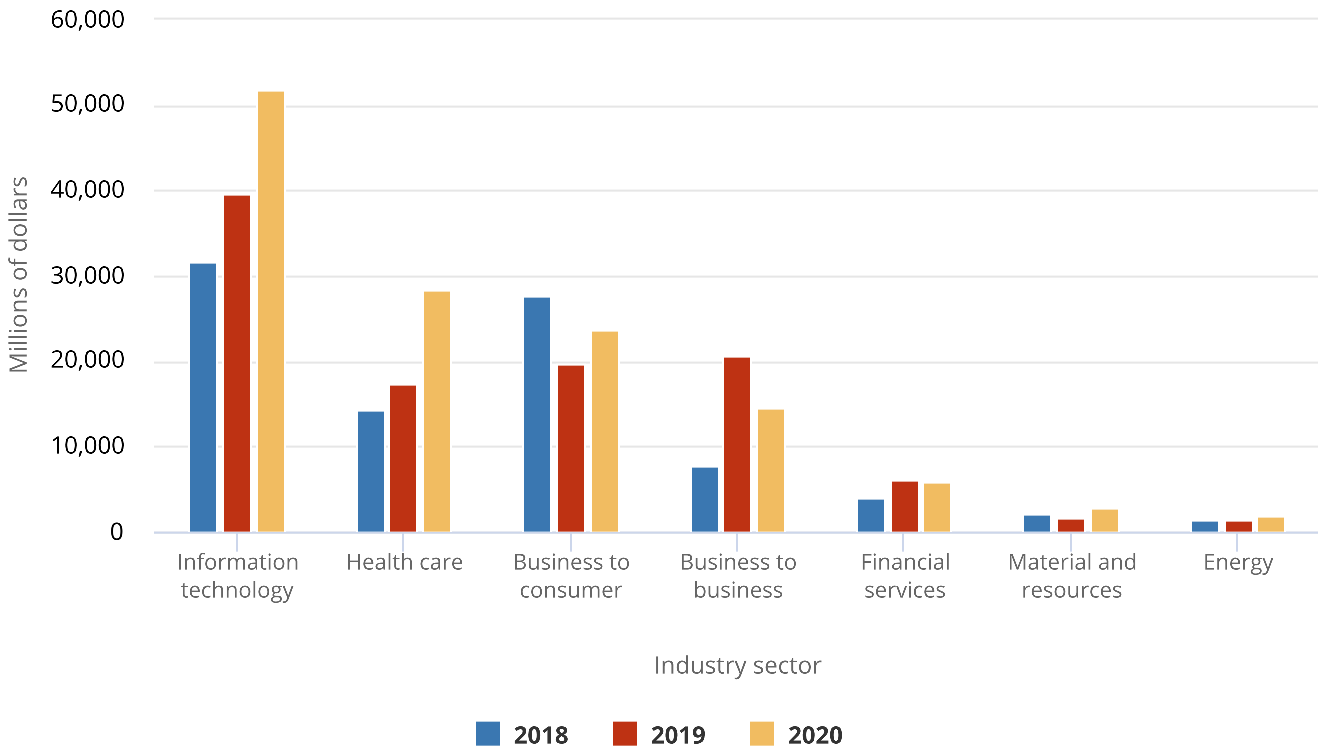
Science and Engineering Indicators

Venture Capital Investment in the United States

Two decades ago, the United States was the main location of venture capital activity, with U.S.-headquartered firms receiving about 75% of annual venture capital investment from 2000 to 2005. Rapid growth in this type of funding activity increased from $2 billion in 2000 to $129 billion in 2020. However, venture capital investment has grown even more rapidly globally; the U.S. share of this total decreased over the same period to 47% in 2020 (Table SINV-98). The rapid growth in venture capital investments by large U.S.-based Internet and software companies, such as Alphabet, Amazon, Facebook, and Microsoft, have contributed to the expansion of investment in information technology firms, a sector that includes hardware, software, and communications services. Investment increased 31% from 2019 to 2020, continuing the growth from the previous year (**Figure INV-24**). This sector contains two industries—communications equipment and software publishers—that reported the greatest number of product and process innovations from 2015 to 2017 in the business survey data described earlier in this report.

Figure INV-24

Venture capital investment received by firms headquartered in the United States, by industry sector: 2018, 2019, and 2020



Note(s):
Information technology (IT) includes communications and networking, computer hardware, semiconductors, IT services, software, and other information technology. Health care includes health care devices and supplies, health care services, health care technology systems, pharmaceuticals and biotechnology, and other health care. Business to consumer includes apparel and accessories, consumer durables, consumer nondurables, retail, transportation, media, restaurants, hotels and leisure, services (nonfinancial), and other consumer product services. Business to business includes commercial products, commercial services, commercial transportation, and other business products and services. Financial services includes capital markets/institutions, commercial banks, insurance, and other financial services. Materials and resources includes agriculture, chemicals and gases, construction (nonwood), forestry, metals, minerals and mining, textiles, and other materials. Energy includes energy equipment, exploration, production and refining, energy services, utilities, and other energy. Industries classified by PitchBook on the basis of the firm's primary industry. See Table SINV-99 for additional detail.

Source(s):
Venture capital and private equity database, PitchBook, accessed 13 September 2021.

Science and Engineering Indicators

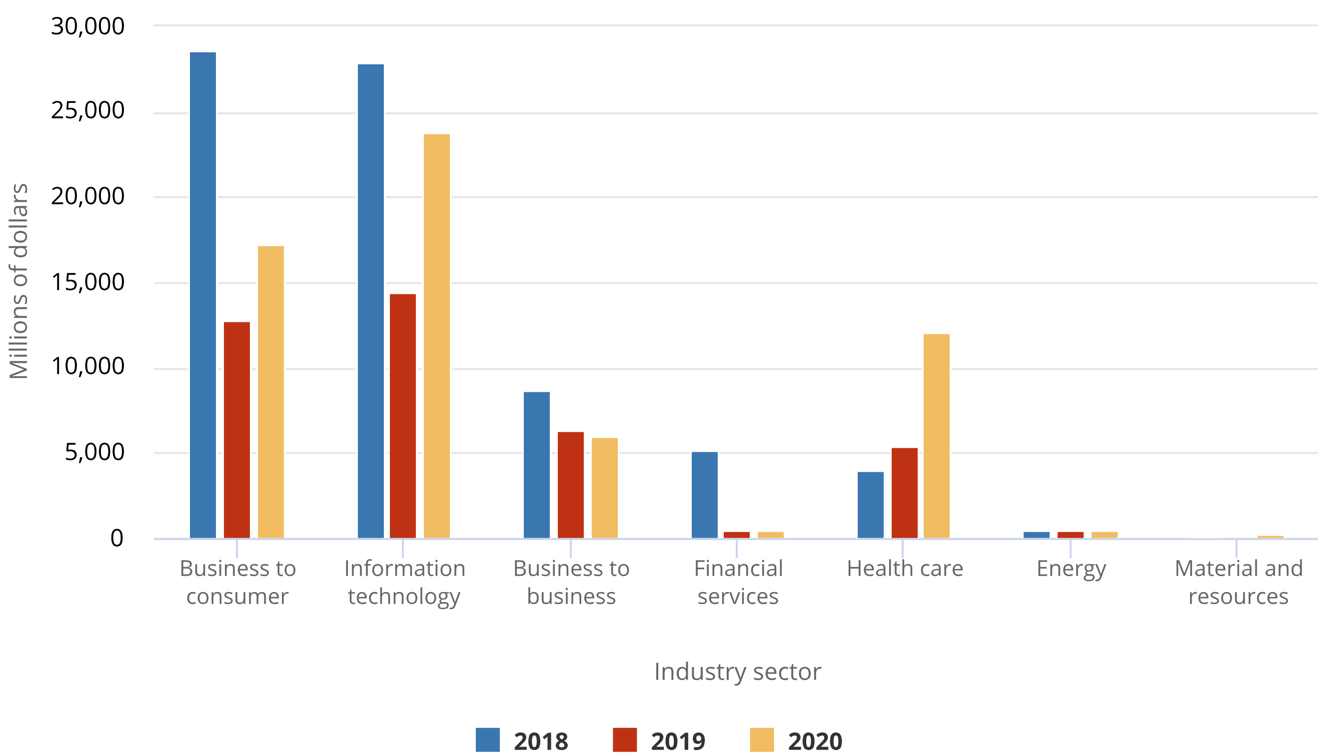
Venture Capital Investment in China

Global venture capital investment from firms headquartered in China was $60 billion dollars globally in 2020, rebounding after the precipitous drop from 2018 to 2019 that broke a decade-long trend of global rapid growth (**Figure INV-23**). The 2019 decline followed the increasing uncertainty for foreign investment in the United States following the passage in 2018 of the Foreign Investment Risk Review Modernization Act (FIRRMA), which broadened the U.S. government's authority to review and respond to national security concerns arising from investments and real estate transactions with foreign persons (U.S. Department of the Treasury 2021).

The investment drops from 2018 to 2019 were largest in the information technology sector and business-to-consumer sector, which provides products and services to consumers (**Figure INV-25**). Both sectors rebounded in 2020. As the COVID-19 pandemic grew in 2020, venture capital investment in firms headquartered in China in the health care sector more than doubled from 2019 to 2020.

Figure INV-25

Venture capital investment received by firms headquartered in China, by industry sector: 2018, 2019, and 2020



Note(s):
Business to consumer includes apparel and accessories, consumer durables, consumer nondurables, retail, transportation, media, restaurants, hotels and leisure, services (nonfinancial), and other consumer product services. Information technology (IT) includes communications and networking, computer hardware, semiconductors, IT services, software, and other information technology. Business to business includes commercial products, commercial services, commercial transportation, and other business products and services. Financial services includes capital markets/institutions, commercial banks, insurance, and other financial services. Health care includes health care devices and supplies, health care services, health care technology systems, pharmaceuticals and biotechnology, and other health care. Energy includes energy equipment, exploration, production and refining, energy services, utilities, and other energy. Materials and resources includes agriculture, chemicals and gases, construction (nonwood), forestry, metals, minerals and mining, textiles, and other materials. Industries classified by PitchBook on the basis of the firm's primary industry. See Table SINV-99 for additional detail.

Source(s):
Venture capital and private equity database, PitchBook, accessed 13 September 2021.

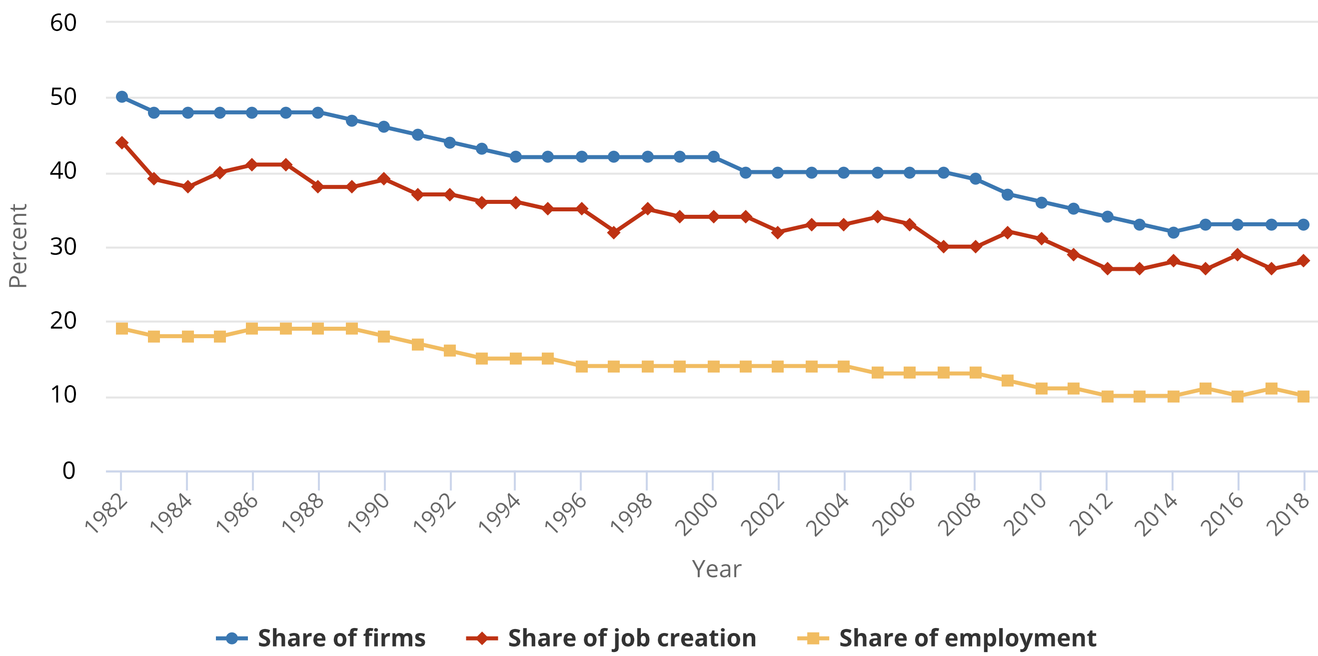
Science and Engineering Indicators

Business Dynamics of New Firms

Firm-level data from the U.S. Census Bureau's Business Dynamics Statistics provide information on establishments opening and closing, firm startups and shutdowns, and the associated impact on employment. The count of new firms that are less than one year old provide an indirect measure of innovation output as it is presumed that a share of these firms is established to bring new innovations to market. Whereas in 1982, half of U.S. firms were 5 years old or younger, the proportion of new firms steadily declined until leveling off at about a third from 2012 to 2018 (**Figure INV-26**). Consistent with this decrease in new firms, young firms accounted for 19% of employment in 1982 but only 10% in 2018 (**Figure INV-26**).

Figure INV-26

Share of firms, job creation, and employment from firms 5 years old or younger: 1982–2018



Source(s):
U.S. Census Bureau, Business Dynamics Statistics, accessed March 2021.

Science and Engineering Indicators

While many factors account for these changes, two relevant explanations are the impacts of technological change and of changing market structure. Technological change can affect business dynamism through productivity shocks to existing firms and through changes in the cost of entry (De Loecker, Eeckhout, and Mongey 2021). High-productivity firms are likely to survive, and increased entry costs will discourage new firms. Changes in the structure of the overall economy can take place as the composition of the business sector shifts toward the service and information sectors and away from manufacturing. While an example of this is the transformation of the retail sector toward *big box* sellers and large national firms, firm and industry analysis show that the effect is more than just a shift in composition (Decker et al. 2014).

Household Innovation

The role of individuals as innovators is less well-measured than for businesses, but that is changing. The latest edition of the innovation measurement handbook, the Oslo Manual, provides a common framework for measuring innovation in a more inclusive manner across the economy, in government, in nonprofit organizations, and in households (OECD Eurostat 2018). Academic researchers have fielded surveys of individuals in several high-income economies, including Canada, Japan, and several European countries. These surveys identify *household innovation*, an activity in which household resources are devoted to creating a product or process that will be used in the future. Data from these pilot surveys indicate about 4% to 10% of the surveyed population reported household innovation activity (Sichel and von Hippel 2019; Søndergaard and Thøgersen 2021).

Data from scientific publications show that patents for computers and communications technologies owned by individuals were cited at similar rates to those owned by businesses (Miranda and Zolas 2017). For other technology areas, the citation rate of patents held by individuals was lower than the rate of patents held by businesses.

The motivations of household innovators differ from those of businesses since they are not usually driven by profit or self-enhancement (Søndergaard and Thøgersen 2021). As a result, they are less likely to pursue IP registration for the associated inventions (von Hippel and Krogh 2003), although there is some patenting by individuals. As reported in the **Invention Indicators: Protecting Useful Ideas** section of this report, individuals accounted for 8% of the USPTO patents awarded in 2020 (**Figure INV-1**).

Government Innovation

Government innovation activity is continuous but often underappreciated. Government innovation output receives occasional attention through coverage, adoption, or dissemination of transformational projects. Examples include the exploration of space, the development of the Internet, and the race to create critically needed vaccines.

To provide a better view into the role of governments in innovation, the United States joined with 40 nations in 2019 to adopt shared principles that include drawing attention to and supporting government innovation (OECD 2019). The EU, Australia, South Korea, New Zealand, the United Kingdom, and five Nordic countries have tested survey-based measurements of innovation in schools, hospitals, universities, and other public workplaces. Quantifiable measures that emerged from this work include in-house innovation activities and education for staff, as well as investment in contract research and acquisitions of new equipment and software for innovation (OECD 2020).

Similar to household innovation, comprehensive indicators for innovation activities in government are not currently available. As reported in the **Invention Indicators: Protecting Useful Ideas** section of this report, patent data from the USPTO indicate the government is a small contributor to inventions, with about 1% of USPTO patents awarded to government assignees in 2020 (**Figure INV-1**). However, this is likely an underrepresentation of the contribution of government to invention because publicly funded R&D performed by the government is often within the public domain and thus not protected IP or is classified due to security concerns and thus not released widely.

SIDEBAR

Sidebar: Rapid Innovation and the Development of the COVID-19 Vaccine

Epidemiologists, doctors, and other scientists worked under extreme time pressure to develop, test, and produce effective vaccines for COVID-19. The contributions of globally recognized universities, government agencies, nonprofit initiatives, and pharmaceutical companies demonstrate the kind of rapid action and knowledge sharing that can take place in emergency situations like the pandemic.

The medical and scientific achievements related to the pandemic were possible due to decades of federally and privately funded research. For more than 50 years, scientists have studied the family of coronaviruses circulating among livestock and poultry that have demonstrated the ability to jump from their original host animals to humans. In the past two decades, members of this coronavirus family that have jumped to humans have caused outbreaks of severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), and the current coronavirus disease (COVID-19). After the emergence of SARS in 2002 and MERS in 2012, coronavirus research expanded significantly. Research on the coronaviruses that cause SARS and MERS provided a stock of knowledge available to scientists, including data on the structure, genome, and life cycle of this family of coronaviruses, when the SARS-CoV-2 virus that causes COVID-19 emerged in December 2019.

The World Health Organization's declaration of a pandemic in March 2020 has led to even more research on coronaviruses and COVID-19 specifically. By October 2020, more than 3,600 trials about COVID-19 had been conducted or were still ongoing; most of these were clinical trials for COVID-19 treatments (OECD 2021). The COVID-19 pandemic has also spurred a large increase in scientific publications, with more than 175,000 articles related to COVID-19 published on PubMed, a resource sharing biomedical and life sciences literature, by September 2021 (NIH 2021). See the *Indicators* report "[2022] Publications Output: U.S. Trends and International Comparisons" for more information on how scientific publication output has changed during the pandemic.

With regard to vaccine development, as of September 2021, there were 114 COVID-19 vaccines in clinical development, including some that were in the development phase at the outset of the pandemic. These vaccine candidates utilize ten different technology platforms, one of which is mRNA-based vaccine technology (World Health Organization 2021). The research underpinnings of mRNA vaccines date back to 1989 (Malone, Felgner, and Verma 1989). In 2005, researchers at the University of Pennsylvania solved a key technical barrier to the use of mRNA in vaccine or drug applications (Karikó et al. 2005), and several biotechnology and pharmaceutical firms, including BioNTech and Moderna, licensed their work hoping to develop marketable pharmaceuticals. Prior to the emergence of SARS-CoV-2, these efforts were largely unsuccessful in bringing products to market. However, all of this work on mRNA technology was useful; it provided knowledge and technologies that enabled researchers to quickly develop mRNA vaccines for SARS-CoV-2. On December 2, 2020, less than a year after COVID-19 was declared a pandemic, the United Kingdom's Medicines and Healthcare Products Regulatory Agency granted temporary regulatory approval for the Pfizer-BioNTech mRNA vaccine, making the United Kingdom the first country in the world to approve an mRNA-based vaccine for use in humans (Lamb 2021).

Conclusion

A dynamic system of innovation activities, including invention, the transfer of knowledge, and the introduction of new products and processes, generates outcomes that range from new modes of mobile communication to new vaccines to counter a pandemic. Historically, participation has tended to be limited to higher-income countries, regions, and economies, and within these locations, participation has tended to be limited to higher-income men. These trends are changing.

Intellectual property indicators, such as patenting and trademarks, show where new products and processes are emerging. Patenting and trademark activity by middle-income countries is increasing. This increasing participation of middle-income countries in IP registration and other innovation activities results in both collaboration opportunities and competition challenges. Additionally, with the global supply chain reliant on international S&E capacity, this interconnectedness generates widespread risk in terms of national security, transmission of disease, and disruption in global and domestic economies.

Both international collaboration and collaboration across sectors within and between countries contributes to globally important innovation activity. Domestically, annual statistics on knowledge transfer at universities and federal labs show growth in research collaborations, technology licensing, and support for startups.

Indeed, the process of innovation, from R&D to invention to the release of a new product or process, can be a long one. Thus, introduction of a new product or process in U.S. businesses is assessed over a 3-year period with the most recent data from 2015 to 2017. In this time frame, one in four U.S. firms reported having introduced a product or process innovation. Federal science investments supported many of the industries with higher-than-average innovation intensities, including health-related industries and industries that produce information and communication technologies. These industries are integral parts of the domestic economy, perform high levels of R&D, and compete globally. Thus, federal science investments play an important role in the overall innovation ecosystem in the United States.

The regional and demographic differences in invention activities (patenting) and innovation activities (trademarking) show that these critical activities are unevenly distributed among demographic groups and among geographic regions. Whereas Black or African American firm owners account for only 2% of all firms, and Hispanic or Latino firms account for only 5% of all firms, these firms reported slightly higher-than-average rates of process and product innovations. Women also participate throughout the system, although their numbers are fewer than those for men. Majority-women-owned firms report higher innovation rates than majority-male-owned firms.

Geographically, county data for the United States on patenting and trademark activity show that the intensity of innovation activities takes place unevenly across the country, with more dense activity in urban and metropolitan areas, along the coasts, and in the Northeast. This is consistent with patterns from other countries as well, where R&D, highly skilled workers, and patenting tend to concentrate in metropolitan areas (Planes-Satorra and Paunov 2017). Concentration supports local growth at the same time that other regions, lacking these attributes, grow more slowly. The underparticipation of large sections of the population provides an opportunity to increase innovation in multiple dimensions.

The data highlighted in this report also illustrate shifts in the locations and types of R&D activities and associated outputs. Chief among these shifts is the rise of China as a global contributor to inventive output and to the transformation of new ideas into innovations, recent cautions about both quality and incentives notwithstanding. Another clear shift is the growing role of universities in private-sector innovation. The last decade has seen a 50% increase in the number of university licenses and license options to private-sector entities. This growth is due to university technology transfer to startups and other small companies, a trend somewhat at odds with the long-term decline in share of firms and employment accounted for by these companies in the U.S. economy.

Invention, knowledge transfer, and innovation are indispensable to improving national and global health, well-being, and security. The indicators reviewed in this report suggest that the global S&E enterprise remains healthy and productive and that long-term trends will continue in the direction of greater output and productivity. The federal government funded basic research decades ago that enabled the rapid development of vaccines for the coronavirus pandemic. The decades-long investment in genetic sequencing and vaccine research bore fruit in the 2020 effort to bring effective vaccines to everyone.

The data in this report raise some questions as well. According to U.S. Census data, more than 400,000 new firms (less than one year old) have been created annually in recent years, but technology transfer data shows impacts for just a few thousand startup firms each year. Clearly, there is unmeasured activity here or *dark innovation* (Martin 2016). Preliminary information in this report on government sharing of OSS and household innovation, and geographic data on new trademarks provides part of the answer, but not all. Taken together with the *Indicators 2022* thematic reports, regional variation matters.

Glossary

Definitions

Citizen science: A form of open collaboration in which individuals or organizations participate voluntarily in scientific progress.

Copyright: A legal protection for original works of authorship, including literary, dramatic, musical, architectural, cartographic, choreographic, pantomimic, pictorial, graphic, sculptural, and audiovisual creations. Definition from U.S. Copyright Office, **https://www.copyright.gov/help/faq/definitions.html**. Accessed March 2021.

Design patent: A grant of a property right to an inventor to protect the visual ornamental characteristics of an article of manufacture.

Economic sectors: Economic activity is organized in national economic accounts into four sectors: business, government, nonprofits serving households, and households. This organization has also been recommended for innovation statistics (OECD Eurostat 2018). In the statistical data in this report, public universities and private nonprofit universities are shown together as *academic* institutions. The term *individuals* refers to the *household* economic sector.

European Union (EU): The EU comprises 27 member nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. As of 2020, the United Kingdom is not a member of the EU. Several figures show the EU 27 plus the United Kingdom.

Innovation: A new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process). The *unit* is a generic term to describe the actor responsible for innovations. It refers to any institutional unit in any sector, including households and their individual members, according to the Oslo Manual, Revision 4 (OECD Eurostat 2018).

Intellectual property: Creations of the mind including inventions, literary and artistic works, and symbols, names, images, and designs used in commerce. Industrial intellectual property includes patents, utility models, trademarks, and industrial designs. Intellectual property covered by copyright includes literary, artistic, and musical works. Available at **https://www.wipo.int/about-ip/en/**. Accessed March 2021.

International patents: These are original patents that have been issued by any international jurisdiction, adjusted to count only the first issuance of a series or family of related patents. The unit of measurement is a patent family that shares a single original invention in common. All subsequent patents in a family refer to the first patent filed, or priority patent and the indicator provides an unduplicated count of original or priority patents in any individual jurisdiction.

Invention: Any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof (U.S. Patent and Trademark Office 2020).

Knowledge transfer: The process by which technology or knowledge developed in one place or for one purpose is applied and used in another place for the same or a different purpose. This transfer can occur freely or through exchange and be deliberate or unintentional. Technology transfer represents a specific case of knowledge transfer that involves the transfer of knowledge embedded in technology.

Mask work: "A series of related images, however fixed or encoded (1) that have or represent the predetermined three-dimensional pattern of metallic, insulating, or semiconductor material present or removed from the layers of a semiconductor chip product; and (2) in which series the relation of the images to one another is that each image has the pattern of the surface of one form of the semiconductor chip product." The definition is provided in the Semiconductor Chip Protection Act (SCPA) of 1984. Available at **https://www.copyright.gov/circs/circ100.pdf**. Accessed March 2021.

Organisation for Economic Co-operation and Development (OECD): An international organization headquartered in Paris, France. At the time of publication, the 38 member countries are Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. Among its many activities, OECD compiles social, economic, and science and technology (S&T) statistics for all member and selected nonmember countries.

Patent family: See international patents.

Patenting intensity: Number of patents per population in a geographic location.

Priority patent: The first patent filed in a family of subsequent patents that refers to the original patent. The original filing may be domestic or from another jurisdiction.

Technical field in patents: *Chemistry*: Biotechnology, pharmaceuticals, organic fine chemistry, microstructural and nanotechnology, chemical engineering, macromolecular chemistry and polymers, basic materials chemistry, materials, metallurgy, surface technology, coating, environmental technology, food chemistry. *Electrical engineering*: Computer technology, electrical machinery, apparatus and energy, semiconductors, digital communication, telecommunications, audio-visual technology, basic communication processes, IT methods for management. *Mechanical engineering*: Other special machines, engines, pumps, and turbines, transport, mechanical elements, machine tools, textile and paper machines, thermal processes and apparatus, handling. *Instruments*: Medical technology, measurement, analysis of biological materials, optics, control. *Other categories*: Civil engineering, other consumer goods, furniture, games.

Technology transfer: The process by which technology or knowledge developed in one place or for one purpose is applied and exploited in another place or for another purpose. In the federal setting, technology transfer is the process by which existing knowledge, facilities, or capabilities developed under federal R&D funding are used to fulfill public and private needs.

Trademark: A word, phrase, symbol, design, or a combination thereof, that identifies and distinguishes the source of the goods of one party from those of others. In this report, trademark refers to both goods and services.

Trade secret: Information that fulfills all of the following requirements, as defined by the USPTO: “Either actual or potential independent economic value by virtue of not being generally known, has value to others who cannot legitimately obtain the information, and is subject to reasonable efforts to maintain its secrecy.” Available at **https://www.uspto.gov/ip-policy/trade-secret-policy**. Accessed March 2021.

U.S. Patent and Trademark Office (USPTO) patent: As defined by the USPTO, a property right granted by the U.S. government to an inventor “to exclude others from making, using, offering for sale, or selling the invention throughout the United States or importing the invention into the United States” for a limited time in exchange for public disclosure of the invention when the patent is granted. Available at **https://www.uspto.gov/learning-and-resources/glossary**. Accessed 15 June 2021.

Utility patent: Intellectual property protection for a potentially useful, previously unknown, and non-obvious invention.

Young firm: A business enterprise that is 5 years old or younger.

Key to Acronyms and Abbreviations

ABS: Annual Business Survey

COVID-19: Coronavirus Disease 2019

CRADA: Cooperative R&D Agreement

DOC: Department of Commerce

DOD: Department of Defense

DOE: Department of Energy

EPO: European Patent Office

EU: European Union

INPADOC: International Patent Documentation

MERS: Middle East respiratory syndrome

mRNA: Messenger Ribonucleic Acid

NASA: National Aeronautics and Space Administration

NCSES: National Center for Science and Engineering Statistics

NSF: National Science Foundation

OECD: Organisation for Economic Co-operation and Development

OSS: Open-Source Software

PCT: Patent Cooperation Treaty

R&D: Research and Development

S&E: Science and Engineering

SARS: Severe Acute Respiratory Syndrome

SBIR: Small Business Innovation Research

STTR: Small Business Technology Transfer

UK: United Kingdom

USDA: U.S. Department of Agriculture

USPTO: U.S. Patent and Trademark Office

WIPO: World Intellectual Property Organization

WIR: Women Inventor Rate

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Notes

1 This corresponds to the USPTO criteria for a utility patent of new, non-obvious, and useful.

2 Population data come from U.S. Department of Commerce, Census Bureau 2021.

3 This adjustment is discussed in greater detail in the **Technical Appendix** and the methodology report prepared by Science-Metrix.

4 Name matching (disambiguation) for this analysis is based on a 6.2 million name database for 182 countries, created using country-level sets of name dictionaries (Martinez, Raffo, and Saito 2016).

5 OSS licenses allow developers to share their software with the public so that others can use, modify, and extend the original computer software programs. Proprietary software, by contrast, is generally not accessible for modification and is not available for use free of charge.

6 The biological and biomedical sciences contributions to patenting take place both before and during the COVID-19 pandemic.

7 As a membership-based organization, its coverage is less than complete; the values reported can be considered a lower boundary.

8 Within these agreements, protected CRADA information means generated information that would have been proprietary had it been obtained from a nonfederal entity instead of from the U.S. federal government.

9 Both the Department of Energy (DOE) and the Department of Defense (DOD) support startups. However, neither department reported startup support to the National Institute of Standards and Technology (NIST) during 2012–2016.

10 Businesses with one to nine employees are now surveyed on innovation activities with the Annual Business Survey-1 (ABS) questionnaire. Businesses with 10 or more employees are surveyed with the ABS-2, which focuses on innovation, technology, intellectual property, and business owner characteristics but not on research and development.

11 Trademarks are assigned to geographic locations based on the county of residence of the trademark holders. To avoid double counting, this report uses fractional counts for trademarks shared by holders in multiple locations; a county receives partial credit for a trademark based on the number of trademark holders who reside in that county divided by all the holders of that trademark. Less than 3% of trademarks are assigned to more than one county.

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